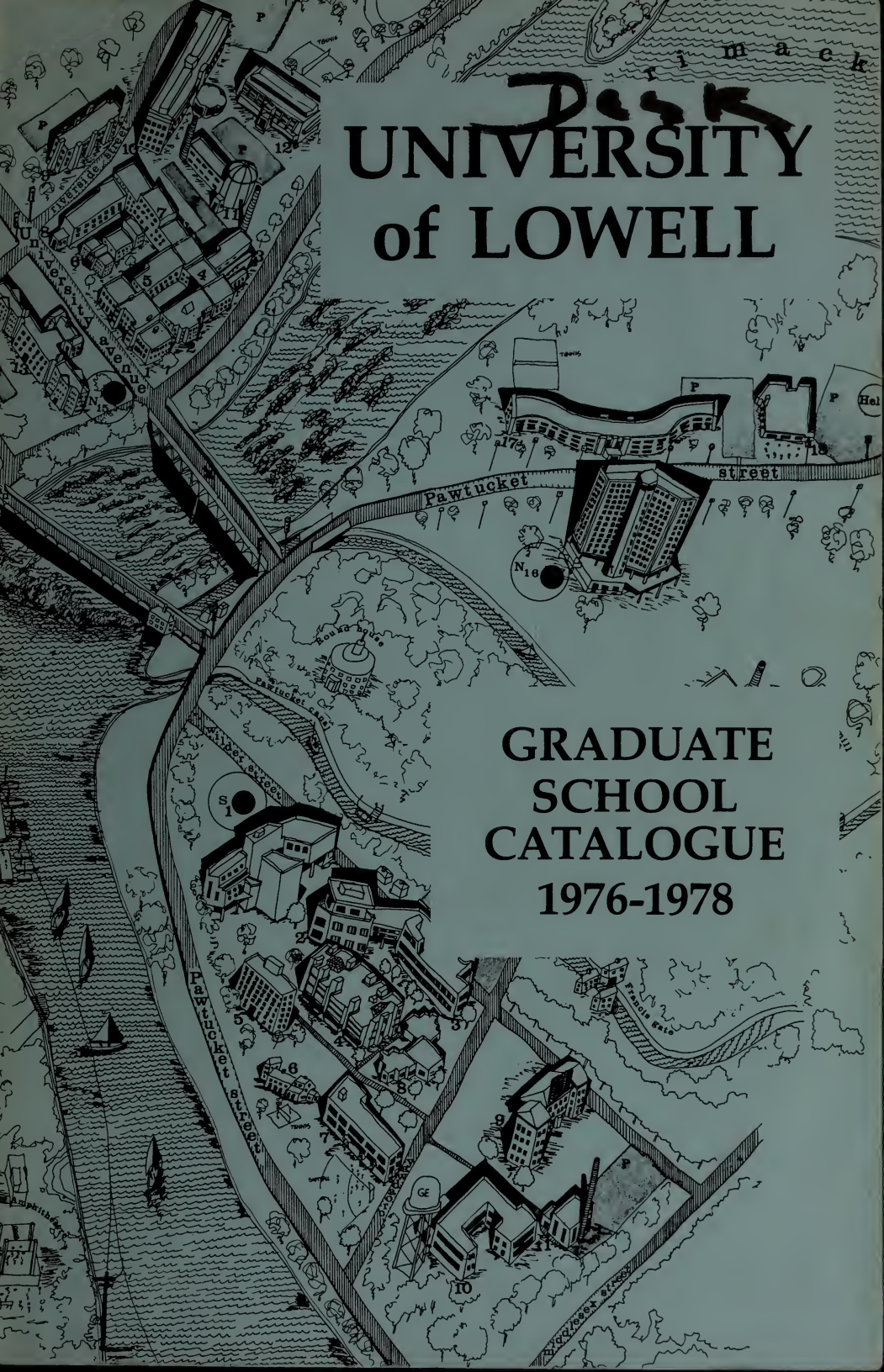
UNIVERSITY
of LOWELL
GRADUATE
SCHOOL
CATALOGUE
1976-1978
Pawtucket street
University avenue
Pawtucket canal
Wilder street
Boarding house
Francis gate
Merrimack river

Graduate School Catalogue

University of Lowell
September 1976

Volume I, No. 1

The University of Lowell does not discriminate in admissions or employment on the basis of sex in compliance with Title IX. Any inquiries should be directed to the Title IX coordinator, Dr. Susan Goodwin, at the University, or the state director of the Office of Civil Rights.

The University of Lowell is an Equal Opportunity Affirmative Action institution and will promote the full realization of equal opportunity through the positive, continuing implementation of an active Affirmative Action program.

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UNIVERSITY OF LOWELL

Lowell, Massachusetts

THE GRADUATE SCHOOL
1976-1978 CATALOGUE

UNIVERSITY OF LOWELL

One University Avenue
Lowell, Massachusetts 01854

Established in 1975

Operated by the Commonwealth of Massachusetts

Day Programs leading to B.S., B.S. in B.A., B.A., B.M., M.S., M.Ed., M.M., M.M.S., M.M.T., Ph.D.

Evening Programs leading to A.B.M., A.A.S., A.S., A. Eng., B.S., M.S., M.Ed., M.M.S., M.M.T.

Member or approved by American Chemical Society, American Council on Education, American Association of Colleges for Teacher Education, College Entrance Examination Board, Council of Graduate Schools in the United States, Engineers Council for Professional Development, National Association of Schools of Music, National Council for the Accreditation of Teacher Education, National League of Nursing, New England Board of Higher Education, Senior College Division of the New England Association of Schools and Colleges, and National Association of Summer Sessions.

The University consists of a North and South Campus along both sides of the Merrimack River, North of the Center of Lowell and 30 miles Northeast of Boston.

Telephone Number: 454-7811, 454-8011 Area Code 617

The University of Lowell Research Foundation conducts research and development for Government and Industry in conjunction with the Colleges of the University.

The Board of Trustees reserves the right to waive at its discretion, any of the rules and regulations stated herein and to change any of the Subjects or Curricula or portions thereof, without prior notice.

TABLE OF CONTENTS

ACADEMIC CALENDAR 1976-1977

Diagnostic Examinations	August 30, 31, September 1
Registration	September 2, 3, 7
Classes Begin	September 7
Last Day to Turn in Clearance Forms for October Degrees	September 14
Columbus Day (University Closed)	October 11
Graduate Record Examination	October 16
Graduate Management Admission Test	October 30
Veterans' Day (University Closed)	November 11
Thanksgiving Recess Begins — 6:00 P.M.	November 24
Classes Resume	November 29
Graduate Record Examination	December 11
Classes End	December 14
Final Examinations Begin	December 15
Last Day of Final Exams — Semester Ends	December 21
Last Day to Turn in Clearance Forms for January Degrees	December 31
Graduate Record Examinations	January 8
Registration	January 13, 14
Classes Begin	January 17
Graduate Management Admission Test	January 29
Washington's Birthday (University Closed)	February 21
Graduate Record Examinations	February 26
Spring Recess Begins — 6:00 P.M.	March 11
Classes Resume	March 21
Graduate Management Admission Test	March 26
Patriot's Day (University Closed)	April 18
Graduate Record Examination	April 23
University Day (Spring Carnival — No Classes)	April 29
Last Day to Turn in Clearance Forms for May Degrees	May 2
Final Examinations Begin	May 7
Last Day of Final Exams — Semester Ends	May 14
Commencement	May 22
First Summer Session	May 24-July 8
Second Summer Session	June 27-August 5
Graduate Record Examinations	June 11
Graduate Management Admission Test	July 9

TENTATIVE ACADEMIC CALENDAR 1977-1978

Diagnostic Examinations	August 29, 30, 31
Registration	September 1, 2, 5
Classes Begin	September 6
Last Day to Turn in Clearance Forms for October Degrees	September 23
Columbus Day (University Closed)	October 16
Graduate Record Examination	October 15
Graduate Management Admission Test	October 29
Veterans' Day (University Closed)	November 11
Thanksgiving Recess Begins — 6:00 P.M.	November 23
Classes Resume	November 28
Graduate Record Examination	December 10
Classes End	December 16
Final Examinations Begin	December 17
Last Day of Final Exams — Semester Ends	December 23
Last Day to Turn in Clearance Forms for January Degrees	December 30
Graduate Record Examinations	January 7
Registration	January 16, 17
Classes Begin	January 17
Graduate Management Admission Test	January 28
Washington's Birthday (University Closed)	February 20
Graduate Record Examinations	February 25
Spring Recess Begins — 6:00 P.M.	March 13
Classes Resume	March 20
Graduate Management Admission Test	March 25
Patriot's Day (University Closed)	April 17
Graduate Record Examination	April 22
University Day (Spring Carnival — No Classes)	April 29
Last Day to Turn in Clearance Forms for May Degrees	May 1
Final Examinations Begin	May 8
Last Day of Final Exams — Semester Ends	May 12
Commencement	May 21
First Summer Session	May 23-July 7
Second Summer Session	June 26-August 4
Graduate Record Examinations	June 10
Graduate Management Admission Test	July 8

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GENERAL INFORMATION

The University of Lowell was created by an Act of the 1973 Massachusetts Legislature, merging Lowell State College with Lowell Technological Institute. The combined institutions have organized diversified graduate programs, based in part on the recognized stature of the former schools in the fields of Nuclear Science and Engineering, Education, Polymer Science, Plastics Technology, and Music. The newest graduate program is Gerontological Nursing, offered by the College of Health Professions.

The University is located in Lowell, a city of about 90,000, and has three major campus areas on the Merrimack River. Primary location for the sciences and technical studies is the North campus, a short distance from the Research Foundation and Fox Student Union Building. The latter is a key center for student campus life, including many activities accessible to graduate students. The South campus is approximately a mile away and includes the Colleges of Education, Liberal Arts, Music and Health Professions. The physical area of the University campuses includes 200 acres and a dollar investment by the Commonwealth of over $100 million.

In addition to being the home of University students, Lowell is the birthplace of artist James McNeil Whistler, Charles Allen, the first Governor of Puerto Rico (his residence is now part of the University), General Benjamin Butler of Civil War fame, and literary figure Jack Kerouac. A working and co-operative spirit exists between Greater Lowell and the academic community.

SPECIAL FACILITIES/PROGRAMS

University Library System

The University Library System is composed of two libraries — the Alumni/Lydon Library at the North Campus and the O'Leary Library at the South Campus. The library holdings include over 250,000 books, periodicals, recordings, scores, microfilm, audio-visual, microfiche (Educational Resource Information Center, ERIC), and non-print materials. Over 250,000 Government Documents are available in a depository collection. The two libraries have a combined seating capacity of over 2,000. Further information and brochures about the University Library System are available at the Circulation and Reference desks of the libraries.

Computer Center

This major facility provides central and remote batch processing facilities for both the academic as well as the administrative needs of the University. Additionally, the system supports over 50 interactive time-sharing terminals, providing direct access to the computing resources of the central computer.

The computer system supports a 'real time' interactive environment, providing facilities for teaching and research in modern techniques of engineering process control systems, engineering graphic design systems, on-line nuclear data acquisition, nuclear reactor safety and control systems, business and industrial management simulation and other similar applications.

At the present time, a CDC-3100 computer with 32K memory serves the academic and administrative computing needs.

Nuclear Science and Engineering Center

The University of Lowell Pinanski Nuclear Center is the most modern nuclear educational facility at any institution at the present time. Although financed by the Commonwealth mainly to serve the nuclear science and engineering curricula of the University, the facilities are available by arrangement to other Massachusetts colleges and universities, and to industrial firms for a variety of research and educational purposes.

The combination of a high power nuclear reactor and the 5.5 MeV Van de Graaff particle accelerator is unique. The complementary facilities make possible undergraduate instructional and graduate research programs which could not be done with either instrument alone.

The Nuclear Center contains laboratories and classrooms for the teaching, administration, and other activities associated with the operation of the reactor and accelerator.

Audio-Visual Centers

There is an Audio-Visual Center on each Campus. The one on North Campus is run mainly by students and services the needs of faculty and students with expertise and projection equipment for films, slides, TV tapes, etc. The Audio-Visual Center on South Campus is located in O'Leary Library and consists of one area where students may work on individual projects. A second area includes three audio-visual classrooms where faculty may bring their classes for the viewing of films, slides, tapes, cassettes, etc. There is in addition a large area where groups of up to 200 can be accommodated. The College of Health Professions uses this Audio-Visual Center for programmed instruction in a large part of the curricula of their several programs.

Durgin Hall

In 1976 the University opened this major complex for the performance, practice and teaching of music. Over 20 University ensembles, orchestras, wind and choral groups perform there throughout the year in the weekly concert series. Sarah Caldwell, Artistic Director of the Boston Opera Company and founder of Opera New England, is scheduled to appear as one of the first guest artists to conduct at Durgin. The facility includes a hall suitable for symphonic productions, seating 1066, and other recital and ensemble areas.

Research Foundation

The Research Foundation was established in 1950 by the Board of Trustees as a not-for-profit organization which operates from income derived from research funded by private industry, foundations and government agencies. Housed in a modern building, the facilities are extensive and supportive to major faculty and student research projects.

Initially formed to assist in applied and affiliated textile research, the Foundation is an integral part of the University. It provides a mechanism for the administration and fiscal management of all academic grants and contracts for Lowell lending invaluable support to the many research programs based in the University Colleges.

Two auxiliary enterprises, the Meteorology and Testing divisions, help defray the overhead costs of the facility. Testing is primarily involved with evaluation of materials by University facilities, including the nuclear reactor. Meteorology services assist industry and government through the repair and calibration of electronic test equipment with traceability to the National Bureau of

Standards. This service is available from the Foundation, or its fully equipped mobile laboratory.

Also based at the Foundation are the Center for Atmospheric Research, and the Center for Schistosomiasis Research, both integral components of the College of Pure and Applied Science.

As part of its close cooperation with the University, the Research Foundation employs both graduate and undergraduate students from the University on a part-time basis. These students gain practical experience which often leads to an advanced degree.

In addition to the research carried out on campus, projects are being worked on in Thailand, Belgium, Greece, Italy, Germany, Algeria and in other parts of the world where the University is becoming known for its significant contributions.

Students are encouraged to visit the Research Foundation.

Further information may be obtained by writing to Dr. Edward L. Alexander, Director of the Research Council, University of Lowell Research Foundation, 450 Aiken Street, Lowell, Massachusetts 01854.

Summer Sessions

All Summer Session Programs are conducted on a self-supporting basis with no financial assistance from the Commonwealth of Massachusetts. Selected graduate credit subjects are offered to matriculated and special students of the university and students of other universities. For detailed information brochures are available upon request from the Graduate School.

The University of Lowell Summer School is a member in good standing of the National Association of Summer Schools (NASS).

Continuing Education

Both non-credit and credit subjects are offered throughout the year under the aegis of the Division of Continuing Education. Most of the programs are held in the evening. Detailed information is contained in brochures available upon request from the Division of Continuing Education of the University of Lowell.

Special Services to Industry and the Community

In addition to the services rendered by the Evening School, the Alumni Association, and the Summer School Program, the University provides such special services to industry and to the community as the following:

Concerts, recitals, and theatrical events both on and off campus;

Industrial seminars and conferences;

Guidance work in the high schools;

Technorama, science fair for area high schools;

Consultive services with the faculty;

Collaboration with the Agency for International Development of the Government in its foreign aid program;

Gerontology Resource Center — A special resource center for gerontological counseling and community services is available to agencies and a variety of Service personnel through the Graduate Nurse Practitioner Program.

Housing

Graduate students may be able to reside in the campus annexes. A list of apartments and rooms for rent may be obtained from the University's Housing Officer.

The University does not sanction or otherwise endorse any housing off the campus, and accepts no responsibility for student residences outside of University supervised facilities.

Health Services

The dispensary is serviced by registered nurses from 8:30 AM-5:00 PM, each school day. Students receive first-aid treatment at the dispensary and are advised as to the best procedure to take in the case of illness. Medical services are available to students 24 hours daily. There are three excellent modern hospitals in the city of Lowell. A low cost health and accident insurance plan is available to all students with optional extended coverage.

Graduate Student Association

The purpose of the Graduate Student Association is to enhance the academic, social, and economic advancement of all graduate students, to represent the graduate student body in University affairs, to establish closer inter-departmental relations among graduate students, faculty, and the administration, and to promote the common interests and better communication among graduate students and with other components of the University community. All graduate students who pay the Graduate Activity fee are members of this organization. All Colleges are represented in its governing bodies.

ADMISSION

General Requirements

To be eligible for admission to the Graduate School, applicants must hold a baccalaureate degree or equivalent from an accredited college or university where a uniformly high scholastic rating has been maintained. Selection of applicants is based on ability to pursue graduate work of high quality.

Application Procedure

Applications may be obtained from the Graduate School office. They should be completed and returned to the Graduate School Office no later than April 1 preceding the fall term in which the applicant wishes to enroll and November 1 for admission in the spring semester. Three letters of recommendation from persons qualified to judge the ability of the applicant to carry on graduate work and research are to be sent directly from these persons to the Graduate School.

Two official copies of all undergraduate and graduate records, with appropriate seal and signatures must be sent directly to the office of the Graduate School by the institutions which the applicant attended. Records and descriptions of subjects must be in English. Each subject must be described in terms of content, scope, number of credits and number of weeks duration.

Credit may be given for graduate subjects taken within the past five years at other accredited colleges if the grade earned is at least *B*, and the subjects were not used in earning another degree. Up to 10 credit hours for the Master's degree or up to 22 credits for the Doctorate may be transferred, subject to appropriate approval. No transfer credit can be granted for the thesis requirements for any graduate degree. Transfer credit for subjects taken before initial enrollment must be cleared within one semester after the student's first registration. No transfer credit for such subjects will be given after this period.

In addition to returning the completed application and having transcripts and letters sent, there are Scholastic Tests specified for various degree programs at the University. These include the Miller Analogies Test, the Graduate Management Admission Test, Music Performance, or the Graduate Record Examinations, both aptitude and the appropriate advanced test, depending upon the specialization proposed in the individual programs and colleges.

All students from countries where English is not the national language must take the "Test of English as a Foreign Language" examination. Students who cannot obtain the TOEFL bulletin and forms locally, should write, well in advance to: Test of English as a

Foreign Language, Box 899, Princeton, New Jersey 08540 U.S.A.

Except in unusual circumstances, applicants are considered and notified of the graduate school decision by June 1 for the fall semester and December 1 for the spring term. Foreign students are urged to apply early, in order to allow time for visa and other arrangements.

Special Student Status

Applicants wishing to take graduate courses without enrolling in a degree program may request admission as a Special Student, and acceptance is contingent upon approval of the Dean of the Graduate School. In some cases, official undergraduate transcripts and scholastic tests may be required. Up to 12 credits earned as a Special Student may be transferred to a regular degree program. Students in this category should follow the regular application procedure, as earlier outlined.

Provisional Student Status

An applicant for admission who is unable to meet all the requirements for general admission may be accepted provisionally.

A provisional graduate student may attain full matriculated status upon demonstration of his ability to pursue graduate studies successfully as measured by completion of his first twelve semester hours work with a minimum of a *B* average in subjects taken for credit toward the graduate degree and the recommendation of the major department.

New England Regional Student Program

The University participates in this reciprocal program by which qualified and legal residents of New England may attend the Graduate School paying in-state tuition charges. Applicants are considered for unique and distinctive graduate level studies not available at their home state university. Full details are available from the New England Board of Higher Education, 40 Grove Street, Wellesley, Massachusetts 02181 or at the University of Lowell Graduate School office.

Application Fee

A recently enacted law of the Commonwealth of Massachusetts, Chapter 684, Acts of 1975, requires an application fee. Residents of the Commonwealth will be charged $10 and non-residents $25. Applications for admission will not be processed until this fee has been received.

ACADEMIC EXPENSES

Tuition (Per Semester)

ACADEMIC YEAR 1976-77

	Fall Sem.	*Spring Sem.*	*Total*
Massachusetts Resident	$236	$258	$ 494
Non-Resident	$650	$650	$1300

ACADEMIC YEAR 1977-78

	Fall Sem.	*Spring Sem.*	*Total*
Massachusetts Resident	$291	$335	$ 626
Non-Resident	$650	$650	$1300

ACADEMIC YEAR 1978-79

	Fall Sem.	*Spring Sem.*	*Total*
Massachusetts Resident	$335	$335	$ 670
Non-Resident	$650	$650	$1300

University Fees* Fall 1976	*GRADUATE/SEMESTER*		*CONTINUING EDUCATION*
	In-state (Inc. N.E. Compact)	*Other*	
Tuition (per credit hour)	Fall $23.60 (up to max of $236) Spring $25.80 (up to max of $258)	Fall $65.00 (up to max of $650) Spring $65.00 (up to max of $650)	$35/contact hr
Audit (per credit hour)	$15	$15	$25/contact hour
Late Fee	$10	$10	$10
Student Union Fee	$25 (full time) $12.50 (part time)	$25 (full time) $12.50 (part time)	
Student Activity Fee	$13 (full time) $8 (part time)	$13 (full time) $8 (part time)	Reg. Fee $5 (I.D. & Ins.)
Commencement Fee	$10 (Must buy own cap & gown)	$10	$10
Dorm Charges	$960/calendar yr	$960/calendar yr	
Lab Fees	$10/Lab	$10/Lab	$10 (if applicable)
Transcript Fee	3 Free upon graduation then $1.00 each additional one		3 Free upon graduation then $1.00 each additional one
Program Fee (continued matriculation)	$5	$5	$5

*Tuition rates will be adjusted higher in 1977 and 1978 in accordance with the above schedule.

Refund Policy

Full-time students (8 or more credits) are eligible for tuition refunds (no fees are refundable) only if they withdraw from the University. Such students must fill out the withdrawal form obtainable in the Graduate office. Tuition refunds are granted in accordance with the following schedule:

No. of Weeks		Refund
At least	But Less than	Rate
0	2	80%
2	3	60%
3	4	40%
4	5	20%
5 and over		None

Part-time students (fewer than 8 credits) are eligible for tuition refunds according to the following schedule if they withdraw from one or more courses:

Before the first class	100%
After the first week but before the second	80%
After the second week but before the third	60%
After the third week	No refund

Students enrolled under the Continuing Education program are eligible for tuition refunds according to the following schedule if they withdraw from one or more courses:

Before the first class	100%
After the first week but before the second	50%
After the second week	No refund

Insurance

Graduate students must purchase accident insurance for $10.25 per academic year. Additional medical-surgical insurance is also available on an optional basis. Waiver of the accident insurance is possible with proof of self-insurance.

Thesis

Every graduate student who completes a thesis is required to bear the cost of microfilming and binding at least two copies of the thesis for the University's files according to the following schedule:

Binding Fee (per copy) $6.50
Microfilm Fee (M.S.) 20.00
Microfilm Fee (Ph.D.) 30.00

Graduate students who have registered for the number of thesis credits required for the degree, but who, in order to complete their thesis, must do further work requiring the use of the laboratory

facilities, must register for 00-701 Research Participation and pay a tuition charge for a minimum of three credits. Graduate students who have completed all the requirements except the writing and defense of a thesis, and do not need to carry out further laboratory work to complete the thesis, must register for one credit hour of 00-601, Continued Matriculation.

Classification

Full-time students register for 8 credits or more per semester. Part-time students register for fewer than 8 credits per semester. Ph.D. candidates who are registered for research credits will be considered full-time for tuition and fee purposes regardless of the number of dissertation credits for which they register.

Financial Aid

Students who need financial aid should request an application for a National Direct Student Loan from the Financial Aid Office. Loans are granted on the basis of need. For more specific information students should contact the Financial Aid Office of the University. A waiver of tuition may be granted to the most deserving with few or no resources up to 2% of the total student population.

Fellowships and Assistantships

No special applications are required, but students who wish to be considered for fellowships or assistantships must have their completed graduate school application material, including transcripts and letters of reference sent to the Dean of the Graduate School no later than February 1.

All fellowship and assistantship applicants must take the appropriate Advance Graduate Record Examination as well as the Aptitude Tests on or before the March examination date, and must be admitted to Graduate School before any action can be taken on their application.

Teaching Assistantships

A limited number of Graduate Teaching Assistantships are available to qualified students working toward a graduate degree. Stipends are approximately $3,300 ($3600 with a master's degree) per academic year, and reappointment in succeeding years is contingent upon satisfactory performance of duties as well as academic achievement. Appointees are expected to carry up to a half-time teaching load, primarily involving supervision of undergraduate laboratories and review sections. Tuition is waived for Graduate Teaching Assistants.

GENERAL REGULATIONS

Graduate Advisory Committee

In order to provide direction for a degree candidate, an Advisor will be appointed as soon as possible after the student arrives on campus. This Advisor will be appointed from among the Graduate Faculty of the student's major department by the chairman, subject to approval by the Dean of the Graduate School. This Advisor is to provide advice and academic counseling to the student relative to his degree program.

The Advisor will also make periodic reviews of the student's progress and make recommendations to the Department Chairman concerning his continuance, dismissal, or recommendation for a degree.

The Student's Advisor will meet with the student as soon as possible after his arrival on campus. His responsibility shall be to:

a. design and approve the program of the student;

b. approve the procedure for satisfying the language requirement (if any);

c. arrange for the Qualifying Exam if the student intends to become a doctoral candidate;

d. report the fulfillment of the above requirements to the chairman of the major department.

As soon as the student has chosen his area of research or project or in the case of a student who has become a doctoral candidate, a Thesis or Dissertation Committee shall be appointed from members of the Graduate Faculty by the Department Chairman subject to approval of the Dean of the Graduate School. The Thesis or Dissertation Committee shall consist of a minimum of three members of the Graduate Faculty, two of whom shall be from the student's major department. The responsibilities of a Thesis or Dissertation Committee shall be to:

a. supervise the research and arrange for the final examination.

b. report the fulfillment of all requirements to the chairman of the major department, the vote of the Committee to be unanimous.

Prior to the final examination of a Ph.D. candidate, an additional member shall be appointed to the Dissertation Committee by the Dean of the Graduate School. This member will act as the representative of the Graduate School and will attend the final examination as a non-voting member. Following the examination this member will file a report to the Graduate School indicating concurrence or lack of it with the general procedures followed in the examination. If the report is negative, the recommendation for approval of the awarding of the advanced degree will be deferred pending action of the Graduate School.

Continuous Registration of Graduate Students

Once a student enrolls in the Graduate School, he is expected to register continuously for every fall and spring term thereafter until his program of studies is complete and his degree has been earned. Normally, he registers for course credits, for research credits, or for both. Students who fail to maintain active status by continuous registration, may not return to graduate study nor register again in the Graduate School except by obtaining formal readmission through the Graduate School office. If a student wishes to interrupt his studies temporarily, he may, with the permission of his advisor, register for one credit hour of 00-602, Approved Leave. Such registration must be employed in each term for which leave status is desired; it is ordinarily not allowed for more than two consecutive terms.

Graduate students who have completed all degree requirements except the writing and defense of a thesis, and who do not need to carry out further laboratory work must, in order to maintain continuous registration, register for one credit hour of 00-601, Continued Matriculation. Master's candidates may register for 00-601 or 00-602 for not more than one academic year; doctoral candidates for not more than three academic years. *A student who fails to maintain continuous registration loses his status as a degree candidate and must apply to the Graduate School for renewal of his candidacy.* If his application is approved, he must pay the late registration fee of $10.00 and the fee for one credit of Continued Matriculation for each semester in which he allowed his registration to lapse.

Graduate students who plan to receive an advanced degree in October must register for the previous Summer Session in order to maintain continuous registration. Each student must take the initiative by submitting a Summer Session application for admission and he must register in person at the time and place specified in the Summer Session Bulletin. Otherwise the Graduate School requirement that a student maintain continuous registration from the time he earns his degree applies only to the regular academic year.

Academic Grades

The following grades will be used for Graduate Students:

Grade	*Quality Points*
A	4.0
AB	3.5
B	3.0
BC	2.5
C	2.0
F	0
P	Pass

In addition the following grades with other designations are as follows:

W	Withdrew from a course or from the University
I	Incomplete
S	Satisfactory (B or better)
U	Unsatisfactory
AU	Audit

Course Numbering System

100-299	Undergraduate credit, lower level
300-499	Undergraduate credit, upper level
500-599	Graduate credit
600 and up	Graduate students only

Graduate Credit for Undergraduate Courses

Courses at the 400 level are designed for seniors but under certain circumstances may be taken by graduate students for graduate credit.

If a graduate student is required to take certain undergraduate courses to make up background deficiencies, no academic petition is needed and the course credit hours are not used as part of the graduate degree requirements. At the time of registration, the graduate student must indicate all courses at the 400 level being taken for graduate credit by placing a G after the course number on the registration card. This will enable the Graduate School and the Registrar to know which courses are being submitted by the student for Graduate credit.

Undergraduate Credit for Graduate Courses

Juniors and seniors who wish to take any course at the 500 level for undergraduate credit must obtain the necessary approvals by means of an Academic Petition Form and the grade received in any such

course is used in calculating the student's cumulative grade point index. Such students may not earn graduate credit until they have completed all requirements for the bachelor's degree.

Academic Grades for Graduate Credit and Graduate Degrees

Graduate credit will be allowed by the Graduate School for grades A, AB, B, BC, C, P, and S. Not more than 6 credits of *BC* and/or *C* will be allowed for the master's degree and not more than 9 credits of *BC* and/or *C* for the Doctor of Philosophy degree. Candidates registering for research and/or seminar will register for 3 and/or 1 credit respectively each semester up to the total number recommended. Grades for research and seminar will normally be *S* or *U* except that grades A, B, etc. can be given for student participation in seminar. In the courses which a student takes to satisfy degree requirements, a minimum standard for satisfactory work is a *B* average. No graduate degree will be awarded to a student whose cumulative average for course work earned at the University of Lowell is below 3.0.

Maximum Credit Load

A graduate student may register for up to 15 credits during the fall and spring semesters and up to 9 credits in the summer. Any student wishing to register for more than the maximum credit load must obtain written permission via the Graduate Academic Petition Form.

Withdrawal

Any student who wishes to withdraw from the Graduate School must obtain a withdrawal clearance form from the Graduate School and have it completed in triplicate. The purpose of this form is to insure that the student's academic and financial obligations are cleared before he leaves the University. If the student fails to complete the withdrawal clearance form and therefore does not withdraw in good standing, official transcripts of the student's academic record will not be issued and the student will not be permitted readmission to the Graduate School except under extenuating circumstances.

Changes in Registration

A. At the discretion and permission of the Student's Advisor, courses may be added or dropped or changed from credit to audit by completing a Graduate Academic Petition Form.

B. Up to and including 10 academic days from the beginning of the semester, a student may add, drop or change courses without

penalty. Courses dropped will not appear in the permanent record. No courses may be added after the 10th day.

C. From the 11th to the 40th academic day of the semester, courses may be dropped without penalty when serious medical or personal problems arise and a grade of *W* will be issued.

D. After the 40th day a student will receive a letter grade for all courses for which he has registered.

Incomplete

The grade of *I* may be given to a student in any course when there is reasonable evidence that the student could not complete the work normally required by the course due to circumstances beyond the student's control. Such circumstances might include missing the final examination because of illness or other similar occurrences. The grade of *I* should be given only if a substantial portion of the work in the course has been completed. To obtain credit for an incomplete, the student must fulfill all requirements of the course to the satisfaction of the instructor.

Grades in Research and Thesis

For courses in Research and Thesis, the student is graded *I* in all such courses until he has fulfilled all thesis or dissertation requirements, including the final defense. At that time the student will receive *S* grades for the maximum number of Research or Thesis credits allowed by his Department. All others will remain graded *I*.

Students registering for 701 Graduate Research will sign up for multiple of 3 credits each semester.

Audit

Students desiring to attend a course on an audit basis must pay $15 per credit hour. No participation is allowed and the student may not take the final examination. No transfer from audit to credit will be allowed.

GENERAL REQUIREMENTS FOR THE MASTER'S DEGREE

Requirements for Degree Conferral

To be recommended for a master's degree, a candidate must satisfy requirements of the Graduate School and the specific requirements of the College in which he is enrolled. The requirements of the Graduate School are given below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master's degree must:

1. Complete a course of study designed by the department in which he is enrolled and approved by the Graduate School. The approved course of study must have a minimum of 30 credit hours of graduate study, including where applicable, a thesis or project in the student's chosen field.

2. Where applicable, complete a master's thesis or a master's project which will consist of scholarly investigation, such as a review, report, synthesis or design in the student's field. The thesis or project must be of the quality expected of graduate study and be approved by the department in which the student is enrolled and by the Graduate School. A thesis reporting the results of research must conform to the format specified in the Thesis Guide, which is available in the Graduate School Office. The only grades given for thesis work are S (satisfactory) and U (unsatisfactory). Four copies of the thesis abstract or project must be filed in the Graduate School Office.

3. Sucessfully pass any oral or written examination on his complete Master's program that the department may require. It is normally expected that a candidate completing original research will take an oral examination dealing mainly with his research problem and that candidates completing other investigations will take an examination more comprehensive in nature.

4. Earn satisfactory grades in all subjects offered for the degree. The lowest grade acceptable for graduate credit is C, but the overall cumulative average of all courses taken must be at least 3.0. Students who earn a C are in danger of being placed on probation. A graduate student's record is reviewed periodically by the Dean of the appropriate College and if at any time, in the judgment of the Dean of the Graduate School, the student is not maintaining the scholastic standards required, he may be asked to withdraw from the University.

All undergraduate subjects taken to clear deficiencies in the student's preparation for graduate work, but which are taken during his enrollment as a graduate student must be passed with a

grade of at least C, however, these courses may not be submitted as part of the course of study leading to the Master's degree.

5. Fulfill departmental language requirements.

6. Satisfy all requirements as to tuition, fees, expenses as evidenced by completing and submitting three copies of the Advanced Degree Clearance form to the Graduate School office.

Term of Residence

Applicants with sufficient background in their chosen field of concentration normally require one to two academic years of residence to complete the requirements for the Master's degree. Those with inadequate background usually require longer terms of study. All requirements for the Master's degree must be completed within five years after the student's formal admission as a matriculated candidate for the degree. Extension of time beyond this limit may be granted only with joint approval of the student's adviser (or advisory committee), his department chairman, and the Dean of the Graduate School. Approved leave for up to a year may be granted to students, who then must maintain their matriculated status by registering for 00-602 Approved Leave.

Veterans

Univ. of Lowell is approved for Veterans Administration benefits.

Veterans eligible for educational benefits should present a copy of their DD214 at registration.

In compliance with Veterans Administration Requirements, all recipients of Veterans Benefits, including eligible children of veterans, must certify their attendance at the University by the following procedure, subject to the penalty of perjury. Every two weeks, students should sign the lists available in the Graduate Office on both campuses. Credit hours should be indicated, and any change in status. Failure to certify attendance must be reported to the Veterans Administration at the end of the month.

Veterans Administration representatives on campus are located in Pasteur Hall, Room 203A.

Cold war and Vietnam Veterans discharged after January 31, 1955 whose service is credited to Massachusetts may be eligible for tuition exemption from the Commonwealth. In order to obtain this exemption a veteran must, at registration, present either a Form 10 from the State Adjutant General or a photostat of his DD214 form, together with a check for the current fees.

The exemption applies only for academic years commencing within ten years of discharge, or within ten years of December, 1966.

Exemption is provided for four years only, and single course enrollments having no connection with overall planned higher education programs are not eligible.

DOCTOR OF PHILOSOPHY REQUIREMENTS

The degree is conferred upon graduates who have met the following requirements:

1. The successful completion of graduate courses in the major fields. The student's Guidance Committee or Advisor will determine the number of graduate credits which the student must earn, but a program consisting of between 70 and 80 credits, including 24 for research, is considered average.

2. The satisfactory completion of the foreign language requirements specified by the major department. (See page 31 regarding overall guidelines for foreign language requirements.)

3. The passing of a comprehensive qualifying examination, oral and written, to be conducted by the major department and to be passed not later than eight months before the completion of the candidate's work. If the student fails the comprehensive examination, he may, at the discretion of the Guidance Committee or Advisor, be permitted a second and final opportunity.

4. Upon passing the qualifying examination the student becomes an official candidate and will be required to hold a Teaching Assistantship for a minimum of two semesters. This requirement may be waived.

5. The preparation of a dissertation based upon the results of original research which is satisfactory to the Dissertation Committee and the major department.

6. The passing of a final oral examination conducted by the Dissertation Committee primarily upon, but not limited to the contents of the candidate's dissertation. The examination cannot be scheduled until all members of the Committee and the major department have approved the dissertation. The oral examination is to be conducted by the Examining Committee. The Examining Committee is to consist of the Dissertation Committee, and such members of the major department as the Department Chairman shall appoint. In order to pass, the candidate must receive the unanimous vote of the Dissertation Committee. Not more than one dissenting vote shall be allowed in the total Examining Committee present.

7. The satisfactory completion of the residence requirement. The equivalent of at least one academic year of full-time graduate work must be spent at the University. The requirement for a year in residence may be satisfied only by the student's physical presence on campus for two consecutive semesters. This may be either a fall-spring sequence or a spring-fall sequence. It cannot be satisfied by a summer session and a semester of the regular school year.

8. All Ph.D. requirements must be completed within eight years after the student's admission as a graduate student. Extension

beyond this time may be granted only with the joint approval of the student's Advisory Committee, his Department Chairman, his College Dean and the Dean of the Graduate School.

9. Student must satisfy all requirements as to the tuition, fees and expenses as evidenced by completing and submitting three copies of the Advanced Degree Clearance form to the Graduate School Office.

GRADUATE READING EXAMINATION IN FOREIGN LANGUAGE

The Graduate School specifies that individual departments establish departmental foreign language requirements for both M.S. and Ph.D. degree candidates according to the levels of competence and overall policy given below. The department will decide the number of foreign languages and the level of competency it wishes to require in each. For purposes of these requirements, a foreign language will be defined as a language other than the student's native tongue and one in which there is a significant body of literature relevant to his academic discipline.

The alternative levels of competency which a department may select are:

1. *Reading level:* Equivalent to the knowledge required in two to four years of undergraduate study.

2. *Journal level:* Knowledge sufficient to understand journals in the language in the student's academic discipline with the aid of a dictionary.

3. No foreign language competency.

A department may select any of these levels or any combination of them for as many languages as it wishes. When a department selects level one, the student's competence will be decided by the Graduate School Foreign Language Test, which is prepared and scored by the Educational Testing Service, Princeton, New Jersey. The passing grade for this level will be specified by the Graduate School Executive Committee. When a department selects level two, the student's competency will be decided by a departmental committee, with the advice and cooperation of the Department of Languages and Literature.

A Master's degree candidate will be expected to satisfy departmental language requirements before formally submitting his thesis or project proposal, and a doctoral student will be expected to satisfy departmental language requirements prior to being admitted to candidacy.

PROGRAMS OFFERED

The University of Lowell Graduate School offers graduate programs in the following areas:

Doctor of Philosophy

Chemistry
Chemistry-Polymer Science Option
Physics

Master of Science

Applied Mathematics
Biological Sciences
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Electrical Engineering
Environmental Studies
Gerontological Nursing
Mathematics
Mechanical Engineering
Nuclear Engineering
Paper Engineering
Physics
Plastics
Polymer Science
Radiological Sciences
Systems Engineering

Master of Education

Curriculum and Instruction
Educational Administration
Reading and Language

Master of Music

Performance
Music Education
Musicology
Music Theory — Composition

Master of Management Science

Master of Business Administration (1977)

Master of Mathematics for Teachers

COLLEGE OF EDUCATION

Graduate Faculty

Margaret R. Shannon, *Dean, and Professor of Education;* B.S., University of Lowell; Ed.M., Ed.D, Harvard University.

Norman F. Benson, *Assistant Professor, Education;* B.S., A.M., University of Minnesota; Ed.D., Ball State University.

M. Virginia Biggy, *Professor of Education and Chairman, Department of Curriculum and Instruction;* B.S., Ed.M., Ed.D., Boston University.

John J. Catallozzi, *Associate Professor, Educational Psychology;* B.S., University of Lowell; Ed.M., Ed.D., Boston University.

William F. Coughlin, *Assistant Professor, Education;* B.S., University of Lowell; A.M., Middlebury College; Ed.D., University of Massachusetts.

Michael T. D'Elia, *Associate Professor, Measurement and Research;* A.B., M.B.A., Dartmouth College; Ph.D., Cornell University.

Alice C. Kiernan, *Assistant Professor, Education;* B.S., University of Lowell; Ed.M., Boston University.

Penelope Z. Kopley, *Assistant Professor, Education;* B.S., University of Lowell; Ed.M., C.A.G.S., Boston University.

Edward R. Lilly, *Assistant Professor, Educational Administration;* A.B., Morgan State College; M.S., City University of New York; Ph.D., University of Connecticut.

Frank J. Luciano, *Associate Professor, Education;* B.S., Ed.M., Ed.D., Boston University.

Richard G. Lyons, *Professor of Educational Philosophy and Chairman, Department of Educational Foundations;* B.S., Ed.M., Ph.D., Boston University.

Anne McParland, *Associate Professor, Education;* B.S. University of Lowell; C.A.S., Harvard University; Ed.M., Ed.D., Boston University

Dorothy V. Meyer, *Assistant Professor, Educational Administration;* A.B., Houghton College; Ed.M., Ed.D., Boston University.

William T. Phelan, *Assistant Professor, Educational Sociology;* A.B., Boston College; A.M., Catholic University; Ph.D., University of Chicago.

Robert B. Wagner, *Assistant Professor, Educational Philosophy;* B.S., Ohio State University; A.M., Kent State University; Ed.D., Harvard University.

The College of Education offers graduate degree programs which provide sophisticated professional preparation for those who aspire to serve in the role of an educational specialist. The degree programs offered and their fields of specialization are *Master of Education* (Ed.M.) in:

Curriculum and Instruction
Educational Administration
Reading and Language

Degree programs in other specializations are currently under consideration.

Admission to Degree Programs in Education

Application Procedure

Application forms may be obtained by contacting the Graduate School Office, University of Lowell, Lowell, Mass., 01854. Each applicant must file the following documents:

1. A completed application form.
2. One copy of his/her teaching certificate must be mailed with the completed application form.
3. Two official transcripts from each undergraduate college and graduate school which the applicant attended. These official transcripts must be sent to the Graduate Office by the colleges which the applicant attended. *Transcripts or copies thereof sent by the applicant are not official and will not be accepted.*
4. Two official copies of the applicant's scores obtained on the Miller Analogies Test must be mailed directly to the Graduate Office by the institution which administered the test.
5. Letters of recommendation from three persons who are qualified to evaluate the applicant's academic and professional abilities. The forms for such recommendations are contained in the admission brochure.

Upon receipt of the above admission documents, the Graduate School Office will forward them to the College of Education. All decisions on admissions are made by the Graduate Committee of the College of Education.

Application Deadline

Completed applications, including all required documents, must be received on or before *April 1,* for candidates who seek admission for the ensuing summer or fall semester, and on or before *November 1,* for candidates who seek admission for the ensuing spring semester.

Applications which are incomplete as of the deadline date, e.g., April 1, will be held for consideration at the deadline date in the following semester, e.g., November 1. Applicants are advised to take the Miller Analogies Test at an early date in order to ensure receipt of the scores by the application deadline.

Applicants will be notified of admission action *in writing;* inquiries via telephone relative to admission action will not be honored. Applicants may expect to receive written notification of admission action by May 15 and December 15 respectively.

Admission Status

Applicants may be admitted to graduate study in Education in one of the following categories.

Degree Candidate: An applicant who meets all requirements for admission and who is admitted to a specific degree program.

Special Student: An applicant who wishes to take graduate courses in Education without enrolling in a degree program may be admitted as a Special Student, contingent upon acceptance by the Graduate Committee of the College of Education. A Special Student may enroll for a maximum of 12 semester hours credit or two consecutive semesters (Fall and Spring), whichever comes first. This status may not be renewed beyond the semester hour/time limitations as stated above.

In the event that a Special Student applies at a later date for admission to a degree program and is accepted, no more than six semester hours credit earned with a grade of *B* or better while enrolled as a Special Student may be transferred to the degree program. These credits must be relevant to the degree program and are subject to approval by the Graduate Committee of the College of Education. A request for transfer of such credits must be made in writing by the applicant and must be filed with his application for admission to a degree program. Transfer of such credits after the student has been granted admission is not permitted.

Non-Degree Students

All students who register for graduate courses in this university without filing a formal application for admission to a degree program in Education or to Special Student status are presumed to be taking graduate courses for reasons other than earning a degree at this university and are classified as *Non-Degree Students*.

In the event that such a student applies for admission to a degree program in Education, no more than six semester hours credit earned with a grade of *B* or better while enrolled as a non-degree student may be transferred to the degree program. Transfer of such credits must be in accordance with the regulations governing transfer credits in the College of Education and which are cited below.

Requirements for Admission

To qualify for admission to a graduate degree program in Education, or for admission as a Special Student, an applicant must have:

1. earned a baccalaureate degree at an accredited college or university;

2. completed his/her baccalaureate degree program with a four-year cumulative average of no less than 2.75;

3. achieved a score at or above the 60th percentile on the Miller Analogies Test;

4. qualified for and been granted a teaching certificate by any state in this country;

5. received approval for admission by the Graduate Committee in the College of Education.

Transfer Credit

Courses completed within five years prior to the date of filing an application for admission to a graduate degree program in Education at this university may be considered for transfer in accordance with the following regulations:

1. No more than six semester hours of graduate credit earned with a grade of *B* or better may be transferred to a master's degree program.

2. A request for transfer of such credit must be made in writing by the applicant and must be filed with his/her application for admission. A request for transfer of such credits after an applicant has been admitted to the program is *not* permitted.

3. An official description of the course(s) must be submitted with the written request.

4. The courses presented must be resident courses completed on the campus of an accredited institution authorized to grant graduate degrees.

5. The courses presented must not have been used in earning another degree.

6. The courses presented must be appropriate to the degree program for which the applicant is applying.

7. Transfer credit may *not* be granted for research seminars, clinical courses, practicums, or internships.

8. The transfer of no more than six semester hours of course credit must be approved by the Graduate Committee of the College of Education.

Confirmation of Admission

Applicants who are granted admission to a degree program or as a Special Student must confirm their acceptance of admission on or before the date designated in the letter of admission.

Application for Readmission

A student who has been admitted to a degree program and who wishes to withdraw from that degree program and enter a different program must file an application in the Graduate School Office for readmission to the latter degree program. Admission is contingent upon the review and approval by the Graduate Committee in the College of Education.

An applicant who has been admitted to a degree program but who fails to enroll in the semester and on the date specified in the letter of admission must file an application for readmission.

A student who fails to maintain continuous registration forfeits his status as a degree candidate and must file an application for readmission. If his/her application is approved, he/she must pay all fees which have accrued. See statement on "Continuous Registration of Graduate Students" elsewhere in this catalogue.

Graduate Advisor

A student who accepts admission will be assigned to a Graduate Advisor in the College of Education. The advisor's responsibility is to 1. provide academic counseling to the student relative to his/her program; 2. approve the program of studies which the student shall present, and also approve all changes in that program; and 3. periodically evaluate the student's academic progress, and to make recommendations to the Graduate Committee concerning the student's continuance, dismissal, or recommendation for a degree.

Degree Requirements

Each graduate student is personally responsible for complying with all the rules and regulations of the Graduate School and the College of Education, and for fulfilling all degree requirements.

In order to qualify for a Master of Education degree, each candidate must meet the following requirements:

1. Complete a minimum of thirty semester hours of required course work in a specific degree program.

2. Complete all course requirements for the degree program on the campus of this University. The sole exception is the maximum of six semester hours of course work taken at another accredited institution which may be approved for transfer at the time of admission.

3. Demonstrate the required proficiency in written English. During the first semester immediately following admission, all students are required to take an examination in written English. If the results of this examination are unsatisfactory, a corrective program must be undertaken and the examination must be taken again.

4. Complete satisfactorily the specified internship under the supervision of a designated faculty member in the College of Education. *This requirement may not be waived.*

5. Complete all course requirements for the degree with a cumulative grade-point average of *B* or better. No additional course credits may be permitted in order to achieve the grade-point average of *B* or better required for the degree.

6. Complete the degree program within five years of the date of notification of admission.

Master of Education Degree Programs

All candidates for a Master of Education degree are required to complete no less than nine semester hours of core requirements in Educational Foundations as delineated below.

Educational Foundations: Core Requirements

Area I — Research
The course entitled 01-621 – *Research Design* is required of all candidates for the Ed.M. degree and it must be completed within the first nine semester hours of course credit earned by each student. A prerequisite for admission to this course is satisfactory completion of an undergraduate course in measurement. This prerequisite may also be met by satisfactory completion of the graduate course entitled 01-521 – *Tests and Measurement.*

All students are required to complete no less than two courses which must be selected from at least two of the following three areas.

Area II — Humanistic Foundations
01-611 Issues in Philosophy of Education
01-612 Contemporary Issues in Education
01-613 Theories of Moral Education

Area III — Psychological Foundations
01-631 Theories of Learning
01-632 Issues in Developmental Psychology
01-633 Dynamics of Organizational Behavior*

*This course is required for all students in the Educational Administration degree program.

Area IV — Sociological Foundations
01-641 Issues in Sociology of Education
01-642 Bureaucratic Organization of Schools and School Systems

Course Descriptions: Educational Foundations

01-521 Tests and Measurement **3**
D'Elia
The course deals with test construction and analysis. Students are required to write, administer, and analyze the results of self-constructed tests. They also evaluate standardized tests. This introductory course is designed for students with no prior background in measurement.

01-522 Statistics **3**
D'Elia
Concentrates on both descriptive and inferential statistics. In de-

scriptive statistics, the topics include central tendency, variability, correlation, and regression. Inferential statistics includes topics such as sampling and analysis of variance. In both areas, application is made to educational problems.

01-531 Dynamics of Group Process **3**

Staff

Participation and experience in a group setting serves as a practical base for an in-depth examination of theories underlying the dynamics of various types of groups.

01-541 Teaching as an Occupation **3**

Phelan

This course focuses on the changing role of teachers in our society. Specifically, problems of professionalization, unionization, and the import of community control are examined. It also considers the social implications of recent legislation, e.g., Mass. Chapter 766, bearing upon classroom instruction and school organization.

01-611 Issues in Philosophy of Education **3**

Wagner

Topics of contemporary concern will be examined with a view to their philosophical basis. Where applicable, views of the great philosophers will be examined relative to these topics.

01-612 Contemporary Issues in Education **3**

Lyons

The course will concentrate on those philosophical disputes which have a direct relationship to the problems of education, namely, the school and social progress, the "open school", the validity of moral judgment, and education in the Third World.

01-613 Theories of Moral Education **3**

Wagner

Traditional and contemporary theories of moral education will be examined to determine differences in underlying assumptions and principles, whether moral education is a proper function of the school, especially in view of recent rulings on the separation of church and state, and assuming that it is, the implications of such theories for the curriculum and school environment. Special attention will be given to the work of Durkheim, Piaget, Kohlberg, Simon, and Skinner.

01-619 Seminar: Justice, Equality, and Education **3**

Wagner

In the first part of this course, attention will focus on the concepts of

justice and equality as fundamental principles governing the structure of society and its institutions. The utilitarian point of view will be examined, but special consideration will be given to the contract theory espoused by John Rawls in his book *A Theory of Justice*, and the analysis of human rights and equality presented by Benn and Peters in *Principles of Political Thought*. Since our ultimate concern will be the implications of these principles for education, for the structure and operation of schools, the second part of the study will be devoted to the more specific issue of educational opportunity and the problems of sexism, racism, and ability grouping which it involves.

01-621 Research Design **3**

D'Elia

The focus of this course is the construction of statistically testable hypotheses, the design of research studies appropriate to the hypotheses, and the application of statistical tests appropriate to the research designs. Evaluation of published research in accordance with established criteria will be required.

01-631 Theories of Learning **3**

Catallozzi

A detailed analysis of the major contemporary learning theories, both behavioral and cognitive. Areas to be covered include: attention, motivation, S-R paradigms, cognitive processes, Gestalt and field theories. Theorists studied include Bruner, Hebb, Kohlberg, Osgood, Piaget, Sears, Skinner, and Werner.

01-632 Issues in Developmental Psychology **3**

Catallozzi

A study of the concepts and methodologies of the major theoretical systems in developmental psychology. Through a study of selected issues, the student will become familiar with both genetic-structural and neo-behavioristic models of development, as well as various methodologies for applying these models in a variety of educational settings.

01-633 Dynamics of Organizational Behavior **3**

Staff

This course examines various factors involved in human behavior in group and organizational settings. Particular attention is given to social psychological variables which operate within organizations, such as leadership, motivation, communication, and decision-making.

01-634 Social Psychology in Education **3**

Catallozzi

A conceptual and empirical study of social behavior within interper-

sonal, group, organizational, and community settings, both formal and informal. The major experimental studies undertaken in the areas of attitude formation, conformity, decision making, game theory, interpersonal attraction, altruism, aggression, etc., will be analyzed.

01-635 Individual Assessment Intelligence I: Wechsler **3**
Prerequisite: 01-521 or equivalent; Permission of Instructor. *Staff*
A laboratory course which provides intensive training in the techniques of administering, scoring, and interpreting the Wechsler Scales: Wechsler Intelligence Scale for Children (WISC), Wechsler Adult Intelligence Scale (WAIS), Wechsler PP Scale of Intelligence (WPPSI). The theories of intelligence on which these tests are based will be considered. Students are required to purchase the test materials.

01-636 Individual Assessment Intelligence II: Binet **3**
Prerequisites: 01-521 or equivalent; Permission of Instructor. *Staff*
A laboratory course which provides intensive training in the techniques of administering, scoring, and interpreting the Stanford-Binet Intelligence Test. The theories of intelligence on which this test is based will be considered. Students are required to purchase the test materials.

01-637 Behavior Analysis and Management **3**
Staff
Considers current theory, research and practice of behavior modification with students. Primary emphasis is given to the analysis of behavior, the application of basic principles, and the techniques employed in the effective management of behavioral problems.

01-641 Issues in Sociology of Education **3**
Phelan
Topics in sociology that have special relevance to the field of education are considered. While coverage is broad, effort is made to be selective of the most crucial problems in the interdisciplinary fields.

01-642 Bureaucratic Organization of Schools and School Systems **3**
Phelan
The structure of schools and school systems is the focus of this course. Issues and problems of authority, communication, decision-making, job satisfaction, work-incentives are considered.

Curriculum and Instruction Degree Program

The program in Curriculum and Instruction is designed for teachers in elementary and secondary schools who wish to specialize in a curriculum field; for those who will provide instructional leadership in the role of team leader or department chairman; and for those who will provide leadership in curriculum development in their role as a curriculum specialist. This program prepares specialists in any one of the following content fields: English Education, Mathematics-Science Education, and Social Science Education.

The degree requirements include the following:

I. Educational Foundations: Core Requirements

Three courses in the field of Educational Foundations, as specified previously, are required.

II. Specialization in Curriculum and Instruction

A. Core Requirements in Curriculum

The following courses are required of all degree candidates.

04-641 Theory and Research in Curriculum
04-642 Planning and Evaluation of Educational Programs
04-643 Curriculum Development: Elementary School, *OR* 04-644 Curriculum Development: Middle School, *OR* 04-645 Curriculum Development: Secondary School
04-649 Internship in Curriculum and Instruction

B. Curriculum Field Specialization

Each degree candidate will specialize in one of the following curriculum fields: English Education, Mathematics-Science Education, or Social Science Education.

The required courses for each of these fields are specified below.

English Education

04-611 Curriculum Problems in English Education
04-612 Innovation and Change in the English Curriculum
04-613 Research Seminar in English Education
Elective chosen from courses numbered 04, 05, or 06.

Mathematics-Science Education

04-621 Curriculum Problems in Mathematics-Science Education
04-622 Innovation and Change in Mathematics-Science Curriculum
04-623 Research Seminar in Mathematics-Science Education
Elective chosen from courses numbered 04 or 05.

Social Science Education

04-631 Curriculum Problems in Social Science Education

04-632 Innovation and Change in Social Science Curriculum
04-633 Research Seminar in Social Science Education
Elective chosen from courses numbered 04 or 05.

Course Descriptions: Curriculum and Instruction

04-611 Curriculum Problems in English Education **3**
Coughlin
Based on the premise that curriculum development in English is made difficult by the uniqueness of the discipline itself, this course examines the nature of that subject matter in all its component parts in conjunction with contemporary curriculum theory. Emphasis is on delineating what it is about English as a subject matter that makes it problematic from a curriculum standpoint with constant attention as to how the problems can be solved.

04-612 Innovation and Change in the English Curriculum **3**
Coughlin
A review of English curriculum developments over the last quarter century with special emphasis on contemporary issues in education and how they affect the English curriculum and teaching. Areas of consideration include censorship, back to basics, minimal-competency testing, open classroom, grouping, values clarification, sophisticated media, the influence of the paperback, and the evaluation of teachers. The course will also consider future curriculum trends.

04-613 Research Seminar in English Education **3**
Prerequisites: 04-611, 04-612. *Coughlin*
A study of significant research in English Education. Each student selects an area of interest, reviews the major research in that area, and presents a critical analysis of the investigations and of his findings. Particular attention is given to recent research and experiments, and to the implications of such research for the teaching of English.

04-614 Use of Children's Literature in the Secondary English Curriculum **3**
Coughlin
Investigates the relationship between theme and form in literature and the nature and process of analytical criticism as a means of understanding and teaching that relationship. The use of children's literature as an effective tool in teaching the analytical method will be examined. Works by Pirsig, Lionni, Burn, Jarrell, Thurber, Melville, Irving, Crane, and others.

04-621 Curriculum Problems in Mathematics-Science Education **3**

Kopley

The course provides an opportunity to consider educational issues and to investigate timely problems in the mathematics or science curriculum according to the special interests of the participants.

04-622 Innovation and Change in the Mathematics-Science Curriculum **3**

Kopley

Examination of instructional techniques and teaching materials in the curriculum revision projects of the mathematics and science areas.

04-623 Research Seminar in Mathematics-Science Education **3**

Prerequisites: 04-621, 04-622. *Kopley*

Focus as needed on the exploration of contemporary research and of curriculum development projects. Application of research to individual investigations and writing in either field of emphasis.

04-631 Curriculum Problems in Social Science Education **3**

Staff

A brief historical review of social science programs will provide the student with a perspective against which to examine current programs (K-12) and to review reactions to those programs in the popular and professional press. The student will measure his knowledge of this field by his competency to analyze and evaluate the programs and the controversies surrounding them.

04-632 Innovation and Change in Social Science Curriculum **3**

Staff

Students will develop a rationale for the social science/humanities curriculum (K-12), building on their knowledge of curriculum design and the requirements of citizenship. They will evaluate "new" programs now in use against that rationale and they will identify the major components of an improved program which will, at the same time, meet the objectives of state mandates, the unique characteristics of students at different age levels, and the demands of citizenship.

04-633 Research Seminar in Social Science Education **3**

Prerequisites: 04-631, 04-632. *Staff*

A final course with special focus on contemporary research in the field and on the research being done in the national and international curriculum projects. The student will apply his research

knowledge to individual investigations and analyses to give evidence of his expertise in his field.

04-641 Theory and Research in Curriculum **3**

Biggy

A study of the nature of the educational experience and the creation of curricula. The contemporary theorists' views of content, concept, experience, and curricula development will be examined and evaluated and matched with the research available in the curricula fields. This course will provide a theoretical base for continued specialization in the fields of curriculum and instruction.

04-642 Planning and Evaluation of Educational Programs **3**

Biggy

A review of the literature on planning and evaluation in both business and education. Consideration of the establishment of priorities, the sources of information for long range planning, assessment procedures, and the sociological impact of goals of education as established by the clientele of the schools — the citizens.

04-643 Curriculum Development: Elementary School **3**

Staff

A review of state mandates which, by law, shape the curriculum of the elementary school, an examination of "new" curricula and the source of these, and finally, the development of a rationale for curricula design appropriate for five to twelve year olds, and an evaluation of the personnel and techniques by which these curricula can be developed.

04-644 Curriculum Development: Middle School **3**

Staff

A review of state mandates which, by law, shape the curricula of the middle school and junior high school, an examination of "new" curricula and sources of these, and finally, the development of a rationale for curricula design appropriate to meet the physical, social, emotional, and intellectual requirements of early adolescents, and an evaluation of the personnel and techniques by which these curricula can be developed.

04-645 Curriculum Development: Secondary School **3**

Staff

A review of state mandates which, by law, shape the curricula of the secondary schools, an examination of "new" curricula and the sources of these, and finally the development of a rationale for

curricula design for a comprehensive secondary school, appropriate for the college bound as well as the student who may terminate his formal schooling. Evaluative measures for assessing the comprehensive program will be examined, and careful consideration will be given to the personnel and techniques by which the programs of a comprehensive secondary school are designed.

04-649 Internship: Curriculum and Instruction **3**

Prerequisite: Permission of the Chairman. *Staff*

Supervised clinical experience. An opportunity to apply the skills and knowledge of curriculum development and evaluation of instruction which have been acquired in previous course work. The student will be expected to illustrate by performance in a school setting, his comprehension of the complexity and of the relationship between curriculum and instruction. This will be accomplished via special tasks designed by the student and faculty with the advice and approval of local administrators. The college faculty member, in consultation with the educational administrator with whom the student works, will evaluate the student's competency.

04-651 Seminar: Issues in Basic Skills Instruction **3**

Biggy

An investigation and evaluation of the call for a return to "basics". Consideration of the causes of renewed interest in "basics" and a review of current instruction in the basic skills. Students will be expected to develop a rationale and historical perspective from which to discuss intelligently "basic skills" instruction.

04-652 Seminar: Issues in Developing Career Awareness Programs **3**

Biggy

This seminar will be concerned with the rationale for career awareness programs; the issues of content and implementation of such programs and the impact of governmental agencies on the establishment of career awareness programs. All pertinent literature will be reviewed and the multifaceted concepts of career awareness will be examined toward the goal of developing a realistic definition and a proposed program of career awareness.

Educational Administration Degree Program

The program in Educational Administration is designed to prepare administrators of elementary and secondary schools at the level of principal or assistant principal.

The degree requirements include the following:

I. Educational Foundations: Core Requirements
Three courses in the field of Educational Foundations, as specified previously, are required.

II. Specialization in Educational Administration
04-642 Planning and Evaluation of Educational Programs
05-611 Educational Organization and Administration
05-612 Politics, Community Relations, and Educational Leadership *OR*
05-613 Issues in Collective Bargaining
05-621 Elementary School Administration *OR*
05-631 Secondary School Administration
05-629 Internship: Elementary School Administration *OR*
05-639 Internship: Secondary School Administration

III. Electives
Two courses selected from the following:
05-661 Educational Decision Making in an Urban Society
05-662 Equal Education Opportunity: An Analysis
05-663 Financial Aspects of School Administration
05-664 Legal Policy and Education

IV. Teaching Experience
Each candidate for the degree in Educational Administration is required to have successfully completed no less than three years of full-time teaching experience in an elementary or secondary school prior to his/her completion of the degree requirements.

Course Descriptions: Educational Administration

05-611 Educational Organization and Administration **3**
Commito
A basic introduction to the field of public administration and to school administration. The course focuses upon the scope of contemporary school administration, its duties and responsibilities, and inter-personal relationships. Students will study programs, services, plant, facilities, personnel, and public relations. Current theory and principles of educational administration will be applied to practices and procedures. Emphasis will be placed on educational leadership roles, and on developing the perspective necessary to understand current problems in public schools.

05-612 Politics, Community Relations, and Educational Leadership **3**

Commito

An analysis of factors affecting the school and the community. Particular attention will be given to such sensitive areas as communication, budget, school committee, parent pressure, and community politics.

05-613 Issues in Collective Bargaining **3**

Lyons

This course is designed from the viewpoint of teachers as employees. Emphasis will be given to organization of local contracts, bargaining, implementation of contracts, accountability, union discipline, social and economic justice, and the philosophy of power and binding arbitration.

05-621 Elementary School Administration **3**

Staff

Analysis of administrative problems in specific educational settings. The purpose of the course, through the use of case study analysis, is to place students in a decision-making situation as an elementary school administrator.

05-629 Internship: Elementary School Administration **3-6**

Prerequisites: 04-642, 05-611, 05-621;
Permission of the Chairman. *Staff*

Supervised clinical experience. Students acquire practical administrative experience in an elementary school under the direction of both the school administrator and a college faculty member.

05-631 Secondary School Administration **3**

Staff

Analysis of contemporary administrative problems in specific educational settings. The purpose of the course, through the use of case study analysis, is to place students in a decision-making situation as a secondary school administrator.

05-639 Internship: Secondary School Administration **3-6**

Prerequisites: 04-642, 05-611, 05-631;
Permission of the Chairman. *Staff*

Supervised clinical experience. Students acquire practical administrative experience in a secondary school under the supervision of both the school administrator and a college faculty member.

05-661 Educational Decision Making in an Urban Society 3

Meyer

This course will explore the various pressures exerting influence upon the decision making process in education such as politics, parents, the school committee, budgets, unionization, social issues, etc.

05-662 Equal Education Opportunity: An Analysis 3

Meyer

Consideration of the concept of equal educational opportunity and the controversies which have developed. The impact of public policy, funding, laws related to education, and patterns of control of educational opportunity will be considered and evaluated by use of the case study method.

05-663 Financial Aspects of School Administration 3

Staff

From a basis of the general economic setting of public education, the course will examine program and conventional budgeting procedures, and techniques of fiscal analysis and projection in decision making.

05-664 Legal Policy and Education 3

Staff

Through examination of cases based on relationships between agencies and individuals who participate in public education, the student will be able to identify, define, and to seek answers to questions of law.

05-665 Supervision of Instruction 3

Staff

The focus of this course is on the interdisciplinary foundations of supervision. Attention will be given to the following areas: function of theory, change, individual and group relationships in organization, staff influence processes, talent utilization, and evaluation.

05-669 Institute on Issues in Teacher Education 3

Biggy

The purpose of this course is to develop a cadre of cooperating teachers in the elementary and secondary schools who would share in the responsibility for preparing prospective teachers in cooperation with college faculty.

Reading and Language Degree Program

The degree program in Reading and Language is designed for those who wish to become specialists in reading and language either as special teachers or as consultants.

The degree requirements include the following:

I. Educational Foundations: Core Requirements

Three courses in the field of Educational Foundations, as specified previously, are required.

II. Specialization in Reading and Language

A. Prerequisite Course Requirements

Two prerequisites for admission to the course entitled "Clinical Assessment of Reading and Language" are satisfactory completion of prior courses both in the teaching of reading in the elementary school and in the teaching of reading in the secondary school. These prerequisites may also be met by satisfactory completion of the graduate courses entitled "Developmental Reading: Elementary School" and "Developmental Reading: Secondary School."

B. Required Courses

06-641 Acquisition of Language
06-651 Etiology of Reading and Language Learning Disabilities
06-652 Clinical Assessment of Reading and Language Disabilities
06-653 Educational Treatment of Reading and Language Disabilities
06-654 Research Seminar in Reading and Language
06-659 Internship: Reading and Language Disabilities

Course Descriptions: Reading and Language

06-521 Literature for Children **3**

Kiernan

The course will examine the importance of literature in the growth of the child, will consider ways of assisting children in developing a taste for best literature, and will pursue strategies of organizing, projecting and evaluating a literature program.

06-522 Literature for Young Adults **3**

Staff

The major emphasis of the course will be the discussion and analysis of the goals of a literature curriculum, and the exploration of various methods for achieving these goals.

06-531 Developmental Reading: Elementary School 3

Staff

The acquisition and development of reading skills by children in the elementary school will be studied. Special emphasis will be placed on the analysis of new curricula, and on methods and materials designed to facilitate the child's reading development.

06-532 Developmental Reading: Secondary School 3

Staff

The continuum of reading skills from childhood through adulthood will be considered, with major emphasis on the acquisition and development of advanced reading skills by students in the secondary school.

06-641 Acquisition of Language 3

McParland

This course investigates the process by which language is acquired. The pertinent research, both historical and current, will be critiqued, methods of investigating and analyzing language studies, and implications of language development in the acquisition of reading and language skills will be discussed.

06-642 Linguistics and Language Learning 3

Staff

Application of the findings of linguistic science to the teaching of reading and language. Selected topics include an introduction to the phonetics, phonology, and syntax of English, their relation to the orthography of English, and dialect differences.

06-651 Etiology of Reading and Language Learning Disabilities 3

Shannon

Considers the causes and theories of reading and language disabilities. Neurological, genetic, cognitive, perceptual, and psychological factors are studied.

06-652 Clinical Assessment of Reading and Language 3

Prerequisites: 06-531 and 06-532 or their equivalents *McParland*

A major concern of the course is the selection and use of appropriate procedures for the purpose of making an adequate clinical and educational diagnosis. This includes the assessment of function and dysfunction in factors associated with language development: receptive, expressive, writing, reading; and the administration and interpretation of individual and group tests of perceptual, motor, and conceptual functioning in reading and language.

06-653 Educational Treatment of Reading and Language Disabilities **3**

Prerequisite: 06-652. *McParland*

Students will be expected to develop realistic corrective programs based on the interpretation of academic, perceptual, motor, and language diagnostic assessment instruments. These programs will include selecting the proper strategies of instruction, the most productive materials, and establishing a framework of time and of evaluation for the programs.

06-654 Research Seminar in Reading and Language Disabilities **3**

Prerequisite: Permission of Instructor. *McParland*

A final course with special focus on the national and international research being done on reading and language. An examination and analysis of that research and a rigorous discussion about the pertinence and proposed implementation of research findings to these fields of instruction will be undertaken.

06-659 Internship: Reading and Language Disabilities **6**

Prerequisites: 06-651, 06-652, 06-653;
Permission of Chairman. *Staff*

Supervised clinical experience. The student is expected to apply the skills and knowledge of diagnosis, perception and evaluation of reading and language disabilities which were gained in preceding courses. He/she is expected to illustrate by performance in a school or clinical setting his comprehension of the complexity of the task, and the interrelationship of diagnostic and corrective work via special tasks designed and evaluated by the college faculty in consultation with the educational administrators and specialists with whom the student works.

COLLEGE OF ENGINEERING

Willian T. Hogan, *Dean,* B.S., M.S., Ph.D.

CHEMICAL ENGINEERING

Members of the Graduate Faculty

Huan-Yang Chang, *Associate Professor of Chemical Engineering;* B.S., Southwest Associate University, China; M.S. University of Rhode Island; Ph.D., Iowa State University.

Ning H. Chen, *Associate Professor of Chemical Engineering;* B.S. National Chekiang University, China; B.Ch.E. Polytechnic Institute of Brooklyn; M.S., University of Missouri; D.Ch.E., Polytechnic Institute of Brooklyn.

Charles J. Higgins, *Professor of Chemical Engineering;* B.S., Lowell Technological Institute. P.E.

Norwood H. Keeney, Jr., *Professor of Chemical Engineering and Acting Chairman of Department;* B.S., Trinity College, Hartford; M.S., University of Maine; Ph.D. University of Manchester, England. P.E.

James A. Mann, *Associate Professor of Chemical Engineering;* B.S., Rensselaer Polytechnic Institute.

Pasquale A. Marino, *Associate Professor of Chemical Engineering; and Assistant Dean of the Graduate School;* B.S., M.S., Northeastern University; Ph.D. University of Connecticut. P.E.

John W. Walkinshaw, *Assistant Professor of Chemical Engineering;* B.S., M.S., M.S. Lowell Technological Institute.

Master of Science Degree Program

The graduate program in chemical engineering is designed to provide the opportunity for advanced studies in the fundamentals and application of chemical engineering principles and to carry out independent research.

The Chemical Engineering Department will consider students for enrollment in the program of graduate studies who have a Bachelor of Science degree in Chemical Engineering from a recognized college. Those without this degree must show proficiency equivalent to a Bachelor of Science degree in Chemical Engineering, including undergraduate prerequisites if necessary.

Credits

A minimum of 30 semester hours of course work and thesis, excluding seminar, will be required for all students enrolled in the Department of Chemical Engineering. Each student shall also enroll in at least 2 semesters of Seminar and during period of thesis research.

Plan of Study

Each student shall file a plan of study with the Department Chairman. This plan must be filed at the time the student has made a selection of his thesis topic and thesis committee. This form will

contain his thesis topic and past and future courses at the University. Any changes shall be made on the "Changes in Plan of Study" form and all changes shall have the prior approval of the Department Graduate Committee. No student shall register for a thesis until he has submitted this plan of study to his committee. The Plan of Study should be filed, in any event, before the end of the student's second semester at University of Lowell.

Core Curriculum

The core curriculum in Chemical Engineering consists of at least 12 semester hours in the following courses:

10-520	Advanced Chemical Engineering Thermodynamics	(3-0)3
10-509	Chemical Engineering Analysis	(3-0)3
10-528	Intermediate Transport Phenomena	(3-0)3
10-503	Absorption and Extraction	(3-0)3
10-524	Advanced Chemical Process	(3-0)3
10-518	Advanced Distillation	(3-0)3

Of the remaining 12 credits of course work, six to nine credits should be in Chemical Engineering as described in the Catalog and three to six hours may be in any 500 series courses in Mathematics, Chemistry, Mechanical Engineering, Environmental Studies, etc. Any exception must have the approval of the Departmental Graduate Committee. In unusual cases credit may be given for 400G level courses in the Department of Chemical Engineering.

Thesis

Each student will be required to undertake a six semester hour thesis. All students will defend their theses when completed according to Graduate School regulations. During the period that the student is enrolled in graduate thesis he will be required to submit brief monthly reports to the staff of the Department showing progress of his thesis and approved by his advisor.

Courses of Study

10-410G Plant Design **(3-0)3**

Staff

Economic principles applied to evaluation and optimization of various chemical engineering processes. Several minor projects and one major design problem requiring written reports and oral presentation. Use of computers in design computations.

10-503 Absorption and Extraction **(3-0)3**

Chang

Principles of separation; phase diagrams and multicomponent mix-

tures; mathematics and graphical solutions to mass transfer problems.

10-505 Colloid Chemistry for Chemical Engineers **(3-0)3**
Keeney
Colloid chemistry principles; zeta potential and its applications; specific problems involving surface chemistry and physics.

10-507 Corrosion and Electrochemical Principles **(3-0)3**
Prerequisite: Permission of Instructor *Staff*
Electrochemical principles and physical chemistry relating to the corrosion of metals. Materials of construction and design compensating for these effects.

10-509 Chemical Engineering Analysis **(3-0)3**
Prerequisite: 10-403, 10-410 *Chen*
Applications of mathematics to chemical engineering problems; unsteady state equations and problems; special graphical solutions; use of computer for solution of complicated problems; specific real engineering problems.

10-511 Structure and Properties of Matter **(3-0)3**
Mann
Fundamental properties of matter as they relate to chemical engineering problems. Materials of construction. Rheological properties of polymeric materials and their application to chemical engineering.

10-514 Advanced Economic Balance **(3-2)4**
Prerequisite: 10-410 *Chen*
Detailed study of several processes from the standpoint of optimization and economics of design. Group design of a specific chemical plant. Use of computers in solutions of design problems.

10-517 Advanced Distillation **(3-0)3**
Prerequisite: 10-503, 10-504 *Chang*
Review of principles of mass separations; applications to multicomponent distillation. Design of columns and analysis of specific systems.

10-520 Advanced Thermodynamics **(3-0)3**
Prerequisite: Permission of Instructor *Chang, Marino*
A critical examination of classical thermodynamics for a chemical engineering viewpoint emphasizing the fundamental laws. General thermodynamic relations are used to develop equations for pure,

ideal gases and real substances. Selected topics in applications of thermodynamics to equilibrium systems, refrigeration and other equipment.

10-524 Advanced Chemical Process **(3-0)3**
Prerequisite: 10-407 *Staff*
Detailed study of several commercial processes from the standpoint of engineering principles and economics. Economics and interrelationships of the chemical industry. Analysis of specific real problems. Factors involved in determination of best design from several alternatives.

10-525 Advanced Heat Transfer **(3-0)3**
Prerequisite: Permission of Instructor *Marino, Chen*
Review of principles of energy transport. Specific problems in convection and radiant heat transfer. Mathematical treatment of unsteady-state heat transfer.

10-528 Intermediate Transport Phenomena **(3-0)3**
Chang, Marino
An advanced study of the mechanics of momentum, heat and mass transfer. The equations of continuity, motion and energy are considered from several systems in steady and unsteady state processes. Transfer coefficients are defined at a microscopic and macroscopic level and the entire subject of unit operations is defined in terms of equations of change. Considerable emphasis is placed upon solutions to problems.

10-530 Advanced Process Dynamics **(3-0)3**
Marino
An advanced treatment of the dynamics of linear and non-linear systems. Detailed study of the block diagram method and the LaPlace transform is used to write the closed and open loop responses to physical and chemical systems. Control system stability is studied and related by the use of Bode diagrams and Nyquist diagrams. System analysis and control by feed forward techniques are also considered, together with experimental methods of obtaining dynamic response data.

10-521 Introduction to Environmental Engineering **(3-0)3**
Prerequisite: Permission of Instructor *Higgins, Mann*
This is an introductory course to the problems of environmental pollution in all its aspects. Air and water pollution are given particular emphasis and special projects are assigned for student investigation. The course is concerned with the assessment and evaluation of

the magnitude of the problem, but does not consider in depth the known or possible solutions to environmental pollution problems.

10-532 Applications of Computers **(2-3)3**
Prerequisite: Permission of Instructor *Staff*
Use of computers in the handling of engineering data. Development of techniques used in optimization problems and in plant design. Analysis of when and where to use computers in efficient solution of engineering problems.

10-601 Chemical Engineering Seminar **(1-0)2**
Staff
Required of all graduate students.

10-651 Selected Topics in Chemical Engineering **(3-0)6**
Staff
Advanced topics in the various fields of chemical engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemical engineering.

10-701 Graduate Research in Chemical Engineering **(0-9)6**
Staff
Every graduate student is required to perform research work done under the supervision of a senior staff member. This thesis or project must be approved by an examining committee appointed by the Department Chairman.

10-751 Advanced Projects in Chemical Engineering **(0-3)2**
Prerequisite: Permission of Department *Staff*
Special projects laboratory undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by the Department Chairman.

CIVIL ENGINEERING

Members of the Graduate Faculty

Nathan Gartner, *Systems Analysis, Transportation and Urban Planning, Traffic Engineering;* Sc.D. Israel Institute of Technology

William B. Moeller, *Hydrology, Water Resources, Sanitary Engineering, Land Use Planning;* Ph.D., University of Connecticut. P.E.

Charles R. Ott, *Sanitary Engineering, Solid Waste Management;* Ph.D., University of Washington. P.E.

Master of Science Degree Program

Graduate study in Civil Engineering is an intensive, design oriented program of instruction at an advanced level of technical sophistication. (Instruction in the M.S.C.E. Program is planned for late afternoon and evening class meetings.) The program includes curricula in the areas of water resources, structural engineering, geotechnical engineering, and land use planning.

It is accepted that individual students have differing needs and career objectives. The program has, therefore, been set up to permit each student, acting together with his advisor, to construct from a designated base a plan of study suitably balanced and in accord with his own objectives.

The philosophy of each of the curricula is as follows:

M.S.C.E. in Water Resources

The Water Resources program affords the opportunity for acquisition of advanced technological expertise directly oriented toward enhancement of professional competence. The guiding philosophy is that while each course will be topic specific the program for each student will provide a coherent package and a sensitivity to the need for a systems approach to problems. Students must have a B.S. in civil engineering, or an acceptable alternative engineering degree.

M.S.C.E. in Structural Engineering

The purpose of this area of study is to provide the student with advanced concepts and techniques which can be applied to the solution of complex structural engineering problems. A B.S. degree in engineering which includes senior level courses in the analysis of statically indeterminate structures and in the design of steel and concrete structures is required.

M.S.C.E. in Geotechnical Engineering

The master's degree program in geotechnical engineering will encompass soil mechanics theory and its application to practical engineering problems in the fields of foundation and soil engineering. The course work will emphasize the engineering properties of soil,

how the properties are determined, and how they are used with soil mechanics theory in the solution of soil and foundation engineering problems. A B.S.C.E. degree or its equivalent is expected with at least one elementary course in soil mechanics and the usual civil engineering background in statics, strength of materials and hydraulics.

M.S.C.E. in Land Use Planning

The program in Land Use Planning is designed to produce graduates who (a) are competent in using advanced techniques for the analysis of the engineering aspects of Land Use Planning; (b) have a clear understanding of the interaction and interdependency of the engineering with the social, economic, environmental and political considerations in planning; and (c) have an overview of Land Use Planning techniques and philosophies.

Given the importance of transportation in planning and development, special emphasis will be given to transportation planning problems.

All M.S.C.E. in LUP students will be required to have completed at least one acceptable intermediate level course in the areas of Statistics (such as 14-585) and in Economics (such as 64-304) before entering the program or they will be required to complete such courses during their first year of attendance. No credit towards the M.S.C.E. in LUP will be granted for completion of these courses.

Before registering for thesis credit, each student will be required to complete a comprehensive examination. Thesis students should be required to show competence in the areas of urban and regional planning, land use analysis and their area of special interest as arranged between them and their advisor.

General Requirements

Applicants who satisfy the Graduate School admission requirements will be assigned to a Graduate Faculty member who will act as their academic advisor. The M.S.C.E. Degree requires the successful completion of a minimum of 30 credit hours. This includes at least 24 hours in class and seminar work at the 500 level for subjects in the major area or appropriate level for subjects in peripheral areas of the student's program and at least 6 hours in preparation of a publishable thesis.

During the first semester an advisory committee will be established for each degree candidate and each candidate will file a plan of study acceptable to the committee. Students accepted on a provisional basis will follow the same procedure. After having enrolled for 9 hours of instruction, the status of provisional students will be reviewed by the faculty who may then either admit them to regular standing or refuse them admission to the degree program.

Those admitted to graduate study as special students may attempt to enroll at a later date as regular students. However, no more than 9 credits of work completed while on special student status will be used toward a degree. Faculty review of the petitioner's performance will follow the same criteria as used for provisional status petitioners. If accepted, the student will thereupon file an acceptable plan of study as required of all degree candidates.

M.S.C.E. in Geotechnical Engineering

Special Requirements
The student entering this program will be expected to have a B.S.C.E. degree or its equivalent, with at least one elementary course in soil mechanics and the usual civil engineering background in statics, strength of materials and hydraulics.

Core Courses
All students will be required to complete the following courses:

14-531 Advanced Soil Mechanics
14-532 Soil Dynamics
14-533 Advanced Foundation Engineering
14-534 Soil Engineering
14-550 Advanced Structural Analysis

Elective Courses
The student is required to complete at least three courses in the following areas:

Engineering Geology
Advanced Numerical Analysis
Engineering Systems Analysis
Finite Element Analysis
Flow Through Porous Media
Rock Mechanics

M.S.C.E. in Land Use Planning

Special Requirements
Statistics: All M.S.C.E. in LUP students will be required to have completed at least an acceptable intermediate level statistics course (such as 14-585) before entering the program or they will be required to complete this course during their first year of attendance. No credit towards the M.S.C.E. in LUP will be granted for completion of this course. Economics: All M.S.C.E. in LUP students will be required to have completed at least an acceptable introductory course in economics (such as 64-304), or they will be required to complete this course during their first year of attendance. No credit towards the M.S.C.E. in LUP will be granted for completion of this course.

Core Courses
All M.S.C.E. in LUP students will have to complete the following:

14-570 Introduction to Planning I
14-571 Introduction to Planning II
14-572 Environmental Aspects in Planning
14-573 Political & Legal Aspects in Planning

Elective Courses
They are also required to choose at least three of the following:

14-521 Remote Sensing
14-581 Engineering Systems Analysis
14-574 Social Quantitative Analysis
14-576 Urban Planning Analysis
14-540 Transportation Planning
14-575 Terrain Analysis

The remaining hours of credit may be taken in any graduate department as approved by the student's academic advisor. Such courses must be oriented to the description, understanding and analysis of planning problems. They should further help the student develop an area of special interest.

Comprehensive Examination
Before registering for thesis credit each student will be required to complete a comprehensive examination. Thesis students should be required to show competence in the areas of urban and regional planning, land use analysis and their area of special interest as arranged between them and their advisor.

M.S.C.E. in Structural Engineering

Special Requirements
A student seeking an M.S.C.E. in structural engineering must have a B.S. degree in engineering which includes senior level courses in analysis of statically indeterminate structures and in the design of steel and concrete structures. Students deficient in these areas must take these courses as prerequisites before they can take advanced courses.

Core Courses
All graduate programs in structural engineering will be developed to meet the needs of the individual; however, each student should take or be able to show proficiency in the following courses:

14-504 Advanced Strength of Materials
14-550 Advanced Structural Analysis

14-551
or Advanced Design in Steel or Concrete
14-552
14-557
or Structural Dynamics or Soil Dynamics
14-534

Elective Courses
Additional courses taken from the Departments of Civil Engineering, Mechanical Engineering, Mathematics, Plastics Technology, Economics, Management, etc., may be used to complete the students' program. At least one course in advanced engineering mathematics must be included in this group.

M.S.C.E. in Water Resources

Special Requirements
Degree program students must have a B.S. in civil engineering, or an acceptable alternative engineering degree.

Core Courses
It is required that students complete two core courses if they intend to specialize in this discipline:

14-581 Engineering Systems Analysis
14-583 Stochastic Concepts in Civil Engineering

Elective Courses
Individual program flexibility is possible by selection of an acceptable complement of elective courses both from within civil engineering and from other areas.

Courses of Study

14-504 Advanced Strength of Materials **(3-0)3**
Staff
Stress and strain at a point; curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections; theories of failure; introduction to the theory of elasticity, elastic foundations.

14-521 Remote Sensing **(3-0)3**
Staff
Electromagnetic energies reflected or emitted by the natural and cultural environment; current remote sensing systems; Imagery interpretation; Automatic image processing; Applications to land-use planning.

14-532 Advanced Soil Mechanics **(3-0)3**

Staff

Basic theories of soil mechanics and their application under practical conditions. It will deal with basic strength principles and stress-strain behavior of clay and cohesionless soil. Physical properties of soils will be determined in a laboratory portion of the course.

14-533 Advanced Foundation Engineering **(3-0)3**

Staff

Design and analysis of foundations required for various types of sub-soil conditions. The common type of shallow and deep foundations will be studied. Exploration and field tests and their application to design will be briefly examined.

14-534 Soil Dynamics **(3-0)3**

Staff

Design of dynamically loaded foundations including the necessary elements of dynamics. Only an elementary dynamics course will be assumed as background. The principles to be developed will apply to dynamic loading due to machinery, earthquakes, or blasting.

14-535 Engineering Geology **(3-0)3**

Staff

An introduction to the concepts and techniques of engineering geology. Topics will include the geology and morphology of glacial deposits; geological features and their engineering significance; use of borings and geophysical exploration techniques; geologic construction materials; ground-water, water supply, solid and liquid waste disposal; erosion and sedimentation associated with construction activities, reservoir silting and shoreline processes; and the geologic factors considered in earthquake engineering. Case studies and term projects dealing with such activities as land-use planning, reservoir silting, water supply, and dam construction will be included. Certain geologic features and construction projects of New England will be visited during the semester.

14-536 Soil Engineering **(3-0)3**

Staff

Soil as an engineering material and its use in earth structures. The types of earth structures to be treated will include road embankments, small earth dams, and compacted fills. The course will cover analysis and design of these structures and the pertinent field and laboratory soil tests necessary to obtain the soil properties. Soil grain and aggregate properties will be correlated with engineering characteristics. Natural slopes and unretained cut slopes will be analyzed

for short term and long term stability. Trips to construction sites will be arranged where possible to view work in progress. The course will also deal with the selection and placement of field instrumentation necessary for construction control.

14-540 Transportation Planning **(3-0)3**

Staff

Principles of transportation system analysis. Demand, supply and equilbrium flows in multi-modal transportation networks. The urban transportation planning process. Collection of basic data, analysis and model building. Prediction of the future use of transportation systems. Evaluation of alternative proposals.

14-550 Advanced Structural Analysis **(3-0)3**

Staff

An advanced treatment of structural theory including analysis of multi-story structures, frames with variable moment of inertia, continuous trusses and bents, torsional problems related to non-circular cross-sections, beam-columns with variable moments of inertia, arches and curved frames. Mathematical treatment of buckling problems with specific applications to civil engineering structural elements.

14-551 Design of Steel Structures **(3-0)3**

Staff

Elastic and plastic design of structural steel systems, residual stresses; beam-columns; torsion; composite steel-concrete members.

14-552 Design of Reinforced Concrete Structures **(3-0)3**

Staff

Strength method; flexure analysis, shear and torsion; beam-columns; deflections; two-way slabs; flat slabs; creep, shrinkage and temperature effects; prestressed concrete.

14-553 Timber Structures **(3-0)3**

Staff

Design of timber members in tension, compression and bending; design of connections, laminated wood trusses and frames.

14-555 Structural Analysis by Matrix and Numerical Methods **(3-0)3**

Staff

Basic structural analyses theories using Energy and Equilibrium techniques. Introductory studies of structures by use of finite differences, finite elements and other iterative methods. Applications to

truss, beam, and plate elements using computers. Special studies in elastic stability.

14-557 Structural Dynamics **(3-0)3**
Staff

Analysis of structures subjected to dynamic loads; free, forced and damped vibrations with one or multi-degrees of freedom; Dynamic response of beams, framed structures, tall buildings and bridges, response to earthquake loadings.

14-559 Advanced Projects in Structural Engineering **(3-0)3**
Staff

Studies of topics of special interest and need of the student in structural analysis and/or design. (By arrangement)

14-561 Physical Chemical Treatment Processes **(3-0)3**
Staff

Theories of physical chemical treatment processes and the laboratory (or pilot plant) techniques necessary to obtain design data for these processes. Treatment processes applicable to natural waters, domestic wastes, and industrial wastes will be studied. In addition to the development of design methods the relationship of these processes to overall environmental quality improvement will be stressed.

14-562 Groundwater Hydrology **(3-0)3**
Staff

Descriptive and analytic treatment of the occurence, movement and fluctuation of groundwaters will be given. The response of groundwater to wells and the methods of obtaining solutions to well pumping problems will be included. Also to be investigated will be aquifer development and the problem of groundwater and aquifer pollution. The hydrology of landfill leachate will be presented.

14-563 Hydraulics of Open Channels **(3-0)3**
Staff

Problems of varied or non-uniform flow in open channels will be investigated including methods for making surface and back-water profile determinations. Applications and typical cases will be of primary interest. Design capability should be enhanced for channel, canal, ditch, storm and sanitary sewer flow problems, and for hydraulics of reservoirs and treatment works under unsteady flow conditions.

14-564 Hydrology **(3-0)3**

Staff

Basic hydrologic concepts; generation of input for design by processing of time series, correlations and frequency distribution.

14-565 Industrial Waste Treatment Processes **(3-0)3**

Staff

An introduction to the unit operations most commonly encountered in industrial waste treatment. Specific industrial applications will be stressed after an understanding of each unit operations has been developed.

14-566 Biological Waste Treatment Processes **(3-0)3**

Staff

An introduction to the techniques used in gathering data necessary for the selection of biological waste treatment trains and prediction of process efficiency. Both aerobic and anaerobic treatment processes will be considered. Laboratory exercises will include bench scale studies of the various processes described in lecture.

14-567 Advanced Fluid Mechanics **(3-0)3**

Staff

Fluid properties, basic laws for a control volume, Kinematics of fluid flow. Basic hydrodynamics, equations of motion for viscous flow applications, boundary layer theory, unsteady flow.

14-570 Introduction to Planning I **(3-0)3**

Staff

Historic background; Planning concepts and procedures; Urban, Metropolitan, River valley, State, regional, national, global plans. Factors which make up a comprehensive plan.

14-571 Introduction to Planning II **(3-0)3**

Staff

Interrelationships between engineering, sociologic, geographic, economic and political factors. Analytical approaches including land-use, transportation, environment and other public service systems.

14-572 Environmental Aspects in Planning **(3-0)3**

Staff

Impact of public and private planning policies on the natural and man-made environment. Environmental Impact analysis, Environmental policies, land-use policy, air and water resources, energy policy, solid wastes.

14-573 Political and Legal Aspects in Planning **(3-0)3**
Staff

Federal and State Agencies' regulating authority. Zoning; Eminent Domain; Subdivision regulation; Planned-Unit development, the Law of Nuisance.

14-574 Social Quantitative Analysis **(3-0)3**
Staff

Traditional social models; Quantitative techniques; Census procedures and sampling techniques; population movement.

14-575 Terrain Analysis **(3-0)3**
Staff

Principles and Applications of photo patterns analysis; Geologic and Geomorphologic patterns; terrain studies; land-use suitability and capability mapping.

14-576 Urban Planning Analysis **(3-0)3**
Staff

Basic quantitative techniques of urban planning and policy analysis; Definition of the planning process, the role of standards and goals, the structuring of problems and information gathering; Specification of alternative solutions and outcomes, estimation of the impacts of solutions on goals, program evaluation and selection and, finally, the management of program implementation; Calculation of need gaps, causal diagrams, sampling and survey research methods, cost-effectiveness and cost-benefit analysis, program evaluation and review techniques, critical path analysis.

14-581 Engineering Systems Analysis **(3-0)3**
Staff

Introduction to methods of operations research, management science and economic analysis as used in the design, planning and managing of complex (engineering) systems; Optimization methods; Organizational networks; Decision analysis.

14-583 Stochastic Concepts in Civil Engineering **(3-0)3**
Staff

This course will present fundamental concepts involved in designing experiments and decision making in engineering; to identify and analyze effects of uncertainties in engineering, define the role and limitations of stochastic concepts in engineering design and decision making. Emphasis is placed on practical applications of mathematical principles and tools of probability and statistics to problems in Civil Engineering.

ELECTRICAL ENGINEERING

Members of the Graduate Faculty

James E. Powers, *Associate Professor of Electrical Engineering and Chairman of Department;* B.S., M.S., Lowell Technological Institute.

Francesco L. Bacchialoni, *Associate Professor of Electrical Engineering;* Dott. Ing., University of Genova.

Roger H. Baumann, *Professor of Electrical Engineering;* S.B., S.M., Massachusetts Institute of Technology, Sc.D., University of Paris.

Peter Burger, *Assistant Professor of Electrical Engineering;* B.S., Vanderbilt University; M.S., Ph.D., Stanford University.

Jane H. Dennis, *Associate Professor of Electrical Engineering;* S.B., S.M., Ph.D., Massachusetts Institute of Technology.

F. Ross Holmstrom, *Assistant Professor of Electrical Engineering;* B.S. University of Washington; M.S., Ph.D., Stanford University.

Earle R. Laste, Jr., *Professor of Electrical Engineering;* B.S., M.S., Northeastern University; Ph.D., Worcester Polytechnic Institute.

Paul J. Murphy, *Associate Professor of Electrical Engineering and Graduate Coordinator;* S.B., S.M., Massachusetts Institute of Technology. P.E.

Martin A. Patt, *Assistant Professor of Electrical Engineering;* B.S., Northeastern University; S.M., Massachusetts Institute of Technology.

H. James Rome, *Assistant Professor of Electrical Engineering;* B.S.E. (E.E.), M.S.E. (E.E.), University of Michigan; Ph.D. (E.E.), University of Pennsylvania

Carl A. Stevens, *Professor of Electrical Engineering;* B.S., M.S., Tufts University; Sc.M., Brown University; Ph.D., Boston University. P.E.

A. David Wunsch, *Assistant Professor of Electrical Engineering;* B.S., Cornell, S.M., Ph.D., Harvard.

Associates of the Graduate Faculty

George P. Cheney, *Instructor in Electrical Engineering;* B.S., M.S., Lowell Technological Institute.

Donn A. Clark, *Assistant Professor of Electrical Engineering;* B.S., Pennsylvania State University; M.S., Northeastern University. P.E.

Frederick A. Rojak, *Associate Professor of Electrical Engineering;* B.S., Pratt Institute; M.S., Lowell Technological Institute. P.E.

David P. Wade, *Associate Professor of Electrical Engineering;* B.S., Lowell Technological Institute; M.S., Northeastern University.

Master of Science Degree Programs

The Electrical Engineering Department offers the following degrees:

1. Master of Science in Computer Engineering (M.S.C.P.)
2. Master of Science in Electrical Engineering (M.S.E.E.)

3. Master of Science in Systems Engineering (M.S.S.E.)

Each of these programs is described in detail following the general policies which are common to all three programs.

General Considerations

Admission Requirements

To be eligible for admission to the Electrical Engineering Graduate Program an applicant must have received a bachelor's degree or equivalent with an acceptable quality of undergraduate work from a recognized college or university. Both the quality and quantity of previous training are considered.

Provisional Student

Students without a complete undergraduate background in engineering but who otherwise show promise of completing graduate work may be allowed to register as provisional students until such time as these deficiencies are removed by completion of the necessary undergraduate courses. Removal of these deficiencies must take priority over all other subjects and the student's status will not change until a petition initiated by the student is approved by the Graduate Curriculum Committee of the Department of Electrical Engineering. No graduate credit is allowed for courses which are required for the removal of the student's provisional status. If the student feels that he has sufficient knowledge of some or all of the required undergraduate courses, he may, in lieu of completing these courses, request a comprehensive examination in each of the specified courses. All necessary examinations will be drawn up and administered by the faculty of the Department of Electrical Engineering.

Academic Advisors

Each graduate student admitted into the Electrical Engineering Department will be assigned an Academic Advisor (A.A.) who will assist him in his selection of courses and who will develop with the student a program which will meet the needs of the student and the requirements for the desired degree.

Options

The requirements for any of the three Master of Science degrees offered by the Department of Electrical Engineering may be satisfied by either of the following options:

Thesis Option

The completion of thirty (30) credit-hours of approved study including a thesis of six (6) credit-hours, certain required courses, and the balance in electives. Normally these electives will be graduate electrical engineering subjects but may, on approval of the student's

academic advisor, be chosen from other engineering or scientific disciplines. These electives may also include all or part of one of the specific concentrations described under the non-thesis option.

Non-Thesis Option

The completion of thirty-three (33) credit-hours of approved study including a three (3) credit-hour seminar course (EE 601) and the successful completion of four (4) courses of three (3) credit-hours each in one concentrated area elected by the student, certain required courses, and the balance in electives. The 16-601 Seminar in Electrical Engineering will require the student to select a topic with the advice and consent of his instructor. In addition to presenting a short paper, the student will be required to make an oral presentation of his investigation and a defense of his work before his class and other faculty members who may choose to attend. Each student will be judged on his clarity of exposition, his knowledge of his subject, his ability to answer questions clearly and effectively, as well as his own participation in the discussion of other papers.

Theses

No student is allowed to register for a thesis until he has achieved the status of "fully-admitted" student and until such time as he has obtained the approval of a written proposal which clearly outlines the extent and nature of his proposed work.

A thesis must be based on the results of analytical and/or experimental work of a creative nature and must unless otherwise authorized be performed under the supervision of a faculty member who may or may not be his Academic Advisor. The student will be required to give an oral defense of his work before his committee, consisting of a major thesis advisor and two other minor advisors. Other faculty members are invited to attend the oral presentation.

Thesis Proposals

Instructions for preparing proposals, as well as detailed specifications for the final written report, are available from the Graduate Coordinator of the Department of Electrical Engineering. A thesis normally carries six (6) hours of credit but may in unusual cases be extended upon approval of a written petition to the Graduate Curriculum Committee.

Credit for Non-graduate or 400 level courses

Although the Master's Degree candidate is normally expected to take graduate level courses for his degree requirements, certain 400 level Electrical Engineering courses and certain Applied Physics and Mathematics courses are acceptable for graduate credit when approved by the Student's Academic Advisor. However, not more than six (6) credit-hours of these courses may be used to satisfy the

degree requirements. (In the M.S.C.P. Program, 16-411 and 16-417 are considered undergraduate prerequisites and will not receive graduate credit.)

Evening Courses
Admission requirements for the part-time evening program leading to the Degree of Master of Science are the same as for the full-time program, and students may progress according to a slower timetable. A limited number of courses are offered through continuing education, and these courses are interchangeable with the corresponding day school courses.

Teaching Assistantships
A limited number of Graduate Teaching Assistantships are available to qualified students working towards a graduate degree. Stipends are approximately $3000 per academic year, and appointees are expected to carry up to a half-time teaching load. Teaching Assistants are not allowed to register for more than half-time academic loads, unless specifically authorized to do so by the Department Chairman. Tuition is waived for Graduate Teaching Assistants. For more details, refer to the catalog section entitled, FINANCIAL AID.

Master of Science in Electrical Engineering Program

The Master of Science Program in Electrical Engineering offers professional training for the student desiring a broader or deeper understanding of such areas as circuit theory, control systems, information and communication theory, electronic circuits, solid state electronics, computer hardware and software, bio-engineering and electromagnetic fields.

Prerequisites
Each student entering the Master of Science Program in Electrical Engineering is expected to have received a Bachelor of Science in Electrical Engineering with an acceptable quality of undergraduate work from a recognized college or university. An applicant with a Bachelor's degree in other engineering or related fields will normally be accepted as a provisional student until such time as the student has completed those undergraduate courses specified by the Graduate Committee of the department. (See Provisional Student.)

Required Courses

Candidates for the degree of M.S.E.E. will be required to complete the following three courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree.

16-509	Linear Systems Analysis*	(3-0)3
16-577	State Variable Analysis of Systems*	(3-0)3
90-584	Analysis of Random Processes**	(3-0)3

*Complete descriptions of these courses can be found under "Courses of Study".

**Complete description of this course can be found under "Mathematics — Courses of Study".

Thesis Option

In addition to the above required courses, students electing the Thesis Option will be required to complete fifteen (15) credit-hours of elective course work and a six (6) credit-hour thesis (16-701), making a total of thirty (30) credit-hours.

Non-Thesis Option

Students electing the Non-Thesis Option will be required to complete the following program of study (total of 33 credit-hours):

1. Nine (9) credit-hours of required courses described above.
2. Twelve (12) credit-hours of courses from one of the concentrations listed below (M.S.E.E.).
3. Nine (9) credit-hours of elective course work.
4. Three (3) credit-hours of Seminar (16-601).

The elective course work must meet the same conditions as those specified under the Thesis Option above.

M.S.E.E. Concentrations

The student may satisfy the twelve (12) credit-hour concentration requirement by selecting any one of the following groups of four (4) subjects. The courses must be taken as a block — these groups cannot be subdivided or intermixed in meeting the concentration requirement.

Control Systems	*Information & Communications*	*Circuits & Systems*
16-513	16-543	16-528
16-515	16-545	16-529
16-517	16-547	16-530
16-519	16-548	16-531

Computer Hardware	*Computer Software*
16-525	16-522
16-561	16-524
16-574	16-563
12-575	16-564

Master of Science in Computer Engineering Program

The Master of Science Program in Computer Engineering offers professional training for the student desiring a broader or deeper understanding of such areas as digital, analog, and hybrid devices and techniques. Although the required courses in this program attempt to provide the essential background in electrical engineering, computer mathematics and programming, and digital systems design, the main thrust of this program is in computer software on the one hand and in the area "between" hardware and software on the other. For brevity we refer to this latter area as *firmware*. It is felt that the detailed study of computer hardware requires a Bachelor of Science in Electrical Engineering Degree or equivalent and hence the hardware concentration is restricted to students with a B.S. in Electrical Engineering.

Prerequisites

Each student entering the Master of Science Program in Computer Engineering is expected to have received a Bachelor of Science degree in engineering, mathematics, or the physical sciences from a recognized college or university with an acceptable quality of undergraduate work.

The following University of Lowell undergraduate courses or their equivalent are considered prerequisites for the M.S.C.P. program and must be taken by those students who are deficient in them.

16-327	Programming and Applications of Digital Computers I	(2-0)2
16-328	Programming and Applications of Digital Computers II	(2-0)2
16-411	Logic Design of Digital Systems I	(3-0)3
16-417	Absolute and Symbolic Programming	(3-0)3

A complete description of these courses can be found in the undergraduate catalog of the University of Lowell.

Applicants who have not taken the above four courses or their equivalent but who otherwise show promise of satisfactorily completing the M.S.C.P. program will be admitted as provisional students until such time as they have removed these deficiencies. Such courses will not count towards the masters degree.

Required Courses

Candidates for the degree of M.S.C.P. will be required to complete the following four courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree.

16-500	Principles of Electrical Engineering*	(3-0)3

12-520	Discrete Mathematics for Computer Engineers	(3-0)3
16-563	System Programming	(3-0)3
16-574	Introductory Digital System Design	(3-0)3

A complete description of these courses can be found under "Courses of Study".

Thesis Option

In addition to the above required courses, students electing the Thesis Option will be required to complete twelve (12) credit-hours of elective course work and a six (6) credit-hour thesis (16-701), making a total of thirty (30) credit-hours.
(See options under Thesis regarding electives.)

Non-Thesis Option

Students electing the Non-Thesis Option will be required to complete the following program of study (total of 33 credit hours):

1. Twelve (12) credit-hours of required courses described above. (See 16-500 exception for B.S.E.E. backgrounds.)
2. Twelve (12) credit-hours of courses from one of the concentrations listed below (M.S.C.P.).
3. Six (6) credit-hours of elective course work.
4. Three (3) credit-hours of Seminar (16-601).

The elective course work must meet the same conditions as those specified under the Thesis Option above.
(See options under Non-Thesis regarding 16-601.)

M.S.C.P. Concentrations

The student may satisfy the twelve (12) credit-hour concentration requirement by selecting either of the following two groups of four (4) subjects. The courses must be taken as a block — these groups cannot be subdivided or intermixed in meeting the concentration requirement.

Software	*Firmware*	*Hardware**
16-522	16-561	16-525
16-523	12-562	16-561
16-524	16-564	12-562
16-564	12-575	12-575

Master of Science in Systems Engineering Program

The Master of Science Program in Systems Engineering offers professional training for students desiring a broader and deeper

*M.S.C.P. candidates with a B.S.E.E. background will not receive graduate credit for 16-500 but must substitute a three-credit hour graduate elective in place of 16-500.

*Students with B.S.E.E. degrees only.

understanding of relatively complex electrical systems, such as controls, communications, computers, and combinations of these systems. Because of the general nature of systems work, the student is not usually expected to have knowledge of the detailed operations of each component but rather an understanding of the salient characteristics and the interactions between components of the system. Hence, it is possible for a student to obtain an interdisciplinary degree by studying in more than one department. In such cases an interdepartmental committee will be formed, and the student's specific program will be formulated.

Prerequisites

Each student entering the Master of Science Program in Systems Engineering is expected to have received a Bachelor of Science degree in engineering, mathematics, or the physical sciences from a recognized college or university with an acceptable quality of undergraduate work. Students who are weak in basic principles of electrical engineering are encouraged to enroll in 16-500.

Required Courses

Candidates for the degree of M.S.S.E. will be required to complete the following three courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree.

16-509	Linear Systems Analysis*	(3-0)3
16-577	State Variable Analysis of Systems*	(3-0)3
90-584	Analysis of Random Processes**	(3-0)3

Thesis Option

In addition to the above required courses, students electing the Thesis Option will be required to complete fifteen (15) credit-hours of elective course work and a six (6) credit-hour thesis (16-703), making a total of thirty (30) credit-hours. (See options under Thesis regarding electives.) Students working for interdisciplinary degrees must have their entire program approved by their interdepartmental committee, as well as the Graduate Curriculum Committee of the Electrical Engineering Department.

Non-Thesis Option

Students electing the Non-Thesis Option will be required to complete the following program of study (total of 33 credit-hours):

1. Nine (9) credit-hours of required courses described above.
2. Twelve (12) credit-hours of required courses which constitute a concentration and which have the prior approval of the

*Complete descriptions of these courses can be found under "Courses of Study".

**Complete description of this course can be found under "Mathematics — Courses of Study".

student's academic advisor and the Graduate Curriculum Committee.

3. Nine (9) credit-hours of elective course work.
4. Three (3) credit-hours of Seminar (16-601).

The elective course work must meet the same conditions as those specified under the Thesis Option above. (See options under Non-Thesis regarding 16-601)

M.S.S.E. Concentrations

Because of the wide range of topical coverage in Systems Engineering and because of the interdisciplinary option, no specific concentrations are delineated. However, the student may satisfy the twelve (12) credit-hour concentration requirement by obtaining the advice and consent of his advisor in setting up a meaningful concentration to suit his needs with prior approval of the Graduate Curriculum Committee.

Master of Science Programs

Numbers in ( ) represent credit-hours — if no number is shown, course is three (3) credit-hours.

Thesis Option (30 credit-hours)				*Non-Thesis Option (33 credit-hours)*		
Electrical Engineering	Computer Engineering	Systems Engineering	Course Category	Electrical Engineering	Computer Engineering	Systems Engineering
16-509	16-500	16-509	Required	16-509	16-500	16-509
16-577	12-520	16-577		16-577	12-520	16-577
90-584	16-563	90-584		90-584	16-563	90-584
	16-574				16-574	
Five Courses (15)	Four Courses[1] (12)	Five Courses (15)	Electives[1]	Three Courses (9)	Two Courses[2] (6)	Three Courses (9)
12-701 (6)	16-701 (6)	28-701 (6)	Thesis or Seminar	16-601	16-601	16-601
			Concentrations[3]	*Control Systems*	*Circuits & Systems*	*Software*	*Depart-mental*
				16-513	16-528	16-522	Four courses
				16-515	16-529	16-523	(12)
				16-517	16-530	16-524	See M.S.S.E
				16-519	16-531	16-564	
				Information & Communications		*Firmware*	*Inter-disciplinary*
				16-543		16-561	Four Courses
				16-545		12-562	(12)
				16-547		16-564	See M.S.S.E
				16-548		12-575	
				Computer Hardware	*Computer Software*	*Hardware*[4]	
				16-525	16-522	16-525	
				16-561	16-524	16-561	
				16-574	16-563	12-562	
				12-575	16-564	16-575	

[1]See *OPTIONS* under Thesis for further specification of electives.

[2]M.S.C.P.'s with B.S.E.E. background will not receive credit for 16-500 but must substitute a (3) credit-hour graduate course.

[3]Students electing the Non-Thesis Option must take one of the concentrations indicated under the desired degree.

[4]Holders of B.S.E.E. degrees only.

Department of Electrical Engineering: Courses of Study

16-500 Principles of Electrical Engineering **(3-0)3**
Prerequisite: B.S. in Engineering or Science *Staff*
Fundamental definitions and circuit laws with applications. Important network theorems such as superposition and Thevenin's theorem. First order transients and forced responses. Diode, transistor, and FET large-signal models. Pulse and digital circuits including transistor and FET switches, waveshaping schemes, multivibrators and logic gates. Switching-speed, propagation times, fan-in and fan-out characteristics of DTL and TTL logic families.

Although this course is primarily intended for students whose undergraduate major was in an engineering or scientific discipline other than electrical engineering, it is also recommended for students who have received their Bachelor of Science in Electrical Engineering degree more than five years ago and who feel the need for a review of electrical principles. In any case, graduate credit will be given only to M.S.C.P. and M.S.S.E. degree candidates not holding a B.S.E.E., while those with the B.S.E.E. degree must substitute a three (3) credit-hour elective to satisfy the requirements for the M.S.C.P. degree.

16-503 Solid-State Physical Electronics I **(3-0)3**
Prerequisite: 16-360 *Staff*
Introduction to the behavior of solid-state electronic devices from the viewpoint of modern physics; review of classical mechanics and Maxwell's equations. The Bohr atom, wave-particle duality, wave packets, Schroedinger's equation, band theory of solids, electrons and holes. Mechanical and acoustical properties of solids, semiconductor behavior.

16-504 Solid-State Physical Electronics II **(3-0)3**
Prerequisite: 16-503 *Staff*
Continuation of EE 503. Semiconductor devices: Schottky diodes, p-n junction devices, junction transistors, field-effect transistors, photo-diodes, varactors. Electro-optic devices, thermo-electric devices, electro-luminescent diodes and laser diodes. Magnetism and magnetic devices.

16-505 Microwave Electronics I **(3-0)3**
Prerequisite: 16-461 *Staff*
Design oriented course dealing with Solid State Active Microwave Devices. Amplifiers, Oscillators, Switches, Modulators, Mixers, Limiters. Realization of Microwave Systems through MIC (Microwave Integrated Circuit) Techniques. Computer Analysis Aids for Microwave Designs.

16-507 Electromagnetics I **(3-0)3**
Prerequisite: 16-461 *Staff*
Maxwell's Equations, Poynting's Theorem, Boundary Value Problems in Electrostatics and Electrodynamics, Green's Functions, Retarded Potentials, Reflection and Refraction of Plane Waves, skin effect, Wave Guides.

16-508 Electromagnetics II **(3-0)3**
Prerequisite: 16-461 *Staff*
Wave Propagation in Plasma and Ferrites, Space Charge Waves, Microwave Circuits, Elementary Antenna Theory, the Dipole, Loop, and Simple Arrays, Huyghen's Principle and Radiation from Apertures.

16-509 Linear Systems Analysis **(3-0)3**
Prerequisite: 16-362 *Staff*
Classical solution of linear systems described by differential equations. Duals, analogs, and electromechanical systems. System function, step and impulse response, and initial conditions. Time-domain convolution. Fournier analysis, series, and integral: impulse method for obtaining transforms. Laplace transforms: evaluation and properties. Complex variable theory: complex differentiation and Cauchy-Riemann equations. Complex integration: Cauchy's theorem and Cauchy's integral formulas. Taylor and Laurent series and the residue theorem inverse LaPlace transforms. Introduction to Z-transforms.

16-513 Linear Control Theory-Analysis **(3-0)3**
Prerequisite: 16-362 *Staff*
Transient performance of linear feedback control systems for determination inputs, using state variable formulation. Block diagram representation and analysis of typical systems. Development and application of Routh-Hurwitz, Nyquist, and root-locus criteria for stability considerations. Comparison of several compensation configurations for both static and dynamic performance criteria, including the effects of specific disturbances. Consideration of controllability and observability.

16-515 Nonlinear Control Systems **(3-0)3**
Prerequisite: 16-413 or 16-513 *Staff*
Analytic and numerical methods for the analysis and design of nonlinear control systems. Phase plane, describing function, the methods of Lyapunov and Popov and other nonlinear analysis techniques are treated.

16-517 Optimal Control Systems **(3-0)3**
Prerequisite: 16-413 or 16-513 *Staff*
A study of the analysis and design of optimal control systems by dynamic programming, calculus of variations, and Pontryagin's Method.

16-519 Discrete Data Control Systems **(3-0)3**
Prerequisite: 16-413 or 16-513 *Staff*
The sampling process, reconstruction of sampled signals, transforms, inverse Z-transforms and flow graph representation of digital systems. The state variable approach to discrete data systems, time solutions by state variable methods. Stability of discrete data systems. Introduction to optimal control of discrete data systems.

12-520 Discrete Mathematics for Computer Engineers **(3-0)3**
Prerequisite: 16-328 *Staff*
Numerical algorithms fundamental to scientific computation. Elementary discussion of error, polynominal interpolation, numerical integration, solution of non-linear equations, function minimization by the method of steepest descent, numerical solution of systems of ordinary differential and difference equations with applications in the study of continuous and discrete-time dynamical systems.

16-521 Automata Studies **(3-0)3**
Prerequisite: 16-412 *Staff*
Mathematical foundation of automata, including probabilistic logics, neuron analog, Turing machines, and learning theory.

16-522 Computer Processing of Non-Numerical Data **(3-0)3**
Prerequisite: 16-328 and 16-417 or Instructor Permission *Staff*
Character strings, character and character substring searches; lists, their storage structures and uses; trees, tree searches, and storage concepts; compiling, polish strings, translating from infix to postfix and prefix, conversion to machine code.

16-523 Compiler Structures **(3-0)3**
Prerequisite: 16-563 *Staff*
Translators and interpreters for programming languages. Syntax of programming languages, syntax directed compilation. Parsing techniques: operator precedence, top down, bottom up and reductive strategies. Intermediate forms and symbol tables. Generation and optimization of machine code. Error handling: detecting and correction. The run time environment, storage allocation.

16-524 Programming Languages **(3-0)3**
Prerequisite: 16-328 *Staff*
An introduction to the formal concepts of programming languages including specification of syntax and semantics. Examination of programming languages (FORTRAN, ALGOL, APL) and string processing languages (SNOBOL). Concepts such as information binding, data storage and mapping and basic control structures are discussed.

16-525 Simulation Techniques **(3-0)3**
Prerequisite: 16-328, 16-445 *Staff*
A study of modern analog, digital and hybrid techniques for the simulation of continuous and discrete systems and processes. The student is expected to study a number of practical engineering systems through the use of simulation techniques on available analog, hybrid and digital computers.

16-528 Advanced Network Analysis **(3-0)3**
Prerequisite: 16-362 *Staff*
Network topology, generalization of circuit equations on a loop, nodal, and mixed basis, using matrix algebra. Linear independence and choosing network variables. Tellegen's theorem, reciprocity, and the properties of passive networks. Quadratic forms. Methods of handling mutual inductance, dependent sources, gyrators, and the like with Thevenin's theorem, superposition, and other network theorems. Impedence by inspection and the relationship between the natural frequencies of a system and the poles and zeros of the impedence and admittance functions. The phase and magnitude relationships of various filters with precorrection for loss effects, using frequency transformations and Hilbert transforms. Butterworth and Chebyshev filters with magnitude and frequency scaling. Properties and interconnections of two-terminal pair networks and Bartlett's bisection theorem.

16-529 Network Synthesis I **(3-0)3**
Prerequisite: 16-362 *Staff*
A review of natural frequencies and analysis techniques; complex variable topics such as conformal mapping, maximum modulus theorem, and Laurent series. Tellegen's theorem. Positive real (p.r.) functions developed from four different viewpoints, including reflection coefficients. Methods for testing p.r. functions; Hurwitz test, Sturm test, and residue tests. Quadratic forms and the testing for p.r. matrices. Properties of the driving point and transfer immittances of LCT, RCT, and RLT networks, Cauer and Foster network realizations, partial pole removals. Cauer transformations. RLCT Brune realizations.

16-530 Network Synthesis II **(3-0)3**
Prerequisite: 16-529 *Staff*
RLCT driving-point synthesis methods of Darlington, Bott-Duffin, Miyata and Fialkow-Gerst. Transfer synthesis methods of Darlington, constant-resistance lattice, RC ladder. Approximation problems using Butterworth functions, dissipation and predistortion techniques. An introduction to active network synthesis.

16-531 Active Network Synthesis **(3-0)3**
Prerequisite: 16-529 *Staff*
Definition and discussion of active network elements such as controlled sources, impedance converters, and impedance inverters. Synthesis techniques using the negative impedance converter, the gyrator, and the infinite gain amplifier will be discussed. The application of the various active elements to modern active filter design will be emphasized.

16-537 Introduction to Bio-Medical Engineering **(3-0)3**
Prerequisite: 16-366 *Staff*
A survey of the use of engineering methods in the life sciences. Topics covered include instrumentation techniques and devices, computer diagnosis of disease, computer aided data analysis, telemetry, ultrasonic techniques, artificial organs, prosthetic devices, biological modeling and simulation. Necessary biological background information is introduced as needed.

16-539 Biological Systems **(3-0)3**
Prerequisite: 16-413, 16-445, 16-537 *Staff*
A discussion of the application of modern control theory to the study of biological systems. Modeling and simulation techniques are emphasized. Necessary biological background information is introduced as required.

16-543 Theory of Communications **(3-0)3**
Corequisite: 16-509 *Staff*
Introduction to information transmission. Representation of deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Introduction to statistical properties of noise. Thermal and shot noise, signal-to-noise ratio, noise figure, and noise temperature. Comparative analysis of continuous and discrete modulation systems; analysis of AM, FM, and various pulse modulation methods (PAM, PPM, PCM) in the presence of noise.

16-545 Coding Theory **(3-0)3**
Prerequisite: 16-577 *Staff*
Concepts and recent developments in the use of codes for error control in data handling systems. Encoding and decoding procedures and their implementation in computational algorithms and hardware organizations are investigated in detail.

16-547 Statistical Communication Theory **(3-0)3**
Prerequisite: 90-584 *Staff*
A study of statistical communication problems. Particular topics include the description of signals and noise as stochastic processes, optimum smoothing and prediction and statistical decision theory.

16-548 Information Theory **(3-0)3**
Prerequisite: 90-584 *Staff*
A study of the probabilistic measure of information transmitted by information sources, the determination of the information handling capacity of communication channels and fundamental coding theorems.

16-549 Introduction to Lasers and Masers **(3-0)3**
Prerequisite: 16-362, 16-461, or equiv. *Staff*
A first course on lasers and masers and their applications. Classical electromagnetic theory as well as introductory Quantum Mechanics serve to provide background to engineering students interested in industrial and scientific laser applications. Typical topics include interferometry, liquid crystals and fiber optics, harmonic generation and holography.

16-551 Electro-Optics **(3-0)3**
Prerequisite: 16-362, 16-461 *Staff*
Principles of optical propagation as described by the Fresnel-Kirchhoff Integral and the Rayleigh integral, concept of transform theory as applied to optical imaging systems, transform theory of conjugate focal plane of lenses in coherent optical systems, geometrical optics as described by Newtonian lens formulae and principles of holographic three-dimensional wave-front reconstruction.

16-561 Computer Organization and Design **(3-0)3**
Prerequisite: 16-411, 16-417 *Staff*
A critical examination of the organization of present day digital computers from both the software and hardware points of view. Computer design with hardware-software trade-off. Comparison of instruction sets, their hardware implementation. Examination of the input-output structures of selected examples. Multi-processing and

parallel processing. Detailed examination of a large system and of several mini-computers. Students are expected to simulate certain aspects of the example computers on available digital computers.

12-562 Microprogramming **(3-0)3**
Prerequisite: 16-563 *Staff*
Microprocessor applications such as digital communication systems, point of sale terminals and process control systems are discussed. The use of programming aids, such as assemblers, editors, compilers, loaders, and debuggers for microprogram development. Software user library subroutine applications. Examples of microprocessor programming of real problems are studied.

16-563 System Programmimg **(3-0)3**
Prerequisite: 16-417 *Staff*
The definition of system programming as programming in a multi-user environment. Programming with and for interrupts. Reentrant programming, pure procedures. Communication between program modules. Nested calls, the push-down stack. Recursive program calls. Reentrant interrupt programming. Activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, macro processes and introduction to assemblers and macro assemblers.

16-564 Operating Systems **(3-0)3**
Prerequisite: 16-411, 16-417 *Staff*
The resources of a large computer system. Sequential and concurrent processes in large digital computers. Design objectives: Program sharing, Multi-processing, Memory-sharing and protection. Process communications and critical processes in operating systems. Scheduling. Paging, Segmenting and swaping strategies. Time sharing and multiple-task operating systems. Design and simulation of operating system behavior. Operating system performance evaluation.

16-571 Introduction to Radar Systems **(3-0)3**
Prerequisite: 16-439 or 16-543 *Staff*
Introduction to both pulsed and C.W. radar systems. Detection of radar echoes in noise. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Moving target indicators (MTI). Pulse compression and other advanced techniques. Discussion of elements of practical radar systems.

16-574 Introduction to Digital System Design **(3-0)3**
Prerequisite: 16-411, 16-417 *Staff*
A review of combinatorial and sequential circuit concepts at both the bit and register levels, number systems, binary adders, shift registers, and memories. The definition of a basic set of control operations and data modules that are used to develop a register-transfer-level language which is used to flowchart and document design algorithms. Computer-assisted simulations, using SIMRIM, are conducted to assist in an evaluation of the cost, performance, and adaptability of each design algorithm. Applications include asynchronous processing, parallel processing, stacks, queues, microprocessing, special purpose processors, and microcoded processors.

12-575 Digital Subsystem Design **(2-2)3**
Prerequisite: 16-574 *Staff*
An overview of the design process developed in EE 574 with emphasis on developing algorithms at the register transfer level, decomposition of these algorithms into detailed RTL flowcharts showing registers, transfer paths, control and timing paths. Selected flowcharts are converted to a detailed wiring diagram for wire-wrap testing and study. A hardware term project is required of each student, constructed from the available register transfer module family along with a complete report detailing the scope and purpose of the algorithm.

16-577 State Variable Analysis of Systems **(3-0)3**
Prerequisite: 16-362 *Staff*
Algebra of matrices, vector spaces, and linear transformations. Calculus of matrices, matrix functions and the solution of differential and difference equations as formulated by the state variable characterization of systems. A consideration of canonical forms for computer simulation.

16-581 Electrodynamics **(3-0)3**
Prerequisite: 16-355 *Staff*
The main focus of this course is the transient analysis of electromechanical devices, including electromechanical transducers and ac and dc machines. Topics covered include stored electric and magnetic energy, electric and magnetic forces, dynamic models of electromechanical devices, solution of differential equations to obtain equations of motion, driving point impedances, transfer functions for linear devices, and methods of approximation for non-linear devices. Applications covered include magnetic transducers, piezo-electric transducers, transient analysis of power systems, and the formulation of mathematical models of servomechanism components.

16-601 Seminar in Electrical Engineering (3-0)3
Prerequisite: Minimum of 15 credit-hours of Graduate Courses *Staff*
The purpose of the seminar is to provide students in the non-thesis option with the opportunity to satisfy the requirement of making a scholarly oral presentation before a group in his field, primarily composed of his class and instructor. Early in the course student proposals will be heard and, if necessary, modified or redefined. Acceptable subjects will include but will not be limited to selected topics in the general field of electrical engineering, lucid descriptions and reviews of compactly written technical journal articles, individual or original topics. Each student will be judged on his clarity of exposition, his knowledge of his subject, his ability to clearly and effectively answer questions, as well as his own participation in the discussions of other papers. Letter grades will be issued (A, B, C, etc.). The class size will be limited to ten students and will meet 3 hours per week for one semester.

16-651 Selected Topics in Electrical Engineering (3-0)3
Prerequisite: Specified at the time of a particular offering *Staff*
Advanced topics in various areas of electrical engineering and related fields. Since topical coverage varies from term to term, a student may be allowed to receive credit more than once for this course.

16-701 Graduate Research in Electrical Engineering (0-9)6
Prerequisite: Minimum of 15 credit hours of Graduate Courses *Staff*
Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering leading to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of electrical engineering.

12-701 Graduate Research in Computer Engineering (0-9)6
Prerequisite: Minimum of 15 credit-hours of Graduate Courses *Staff*
Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering leading to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of computer engineering.

28-701 Graduate Research in Systems Engineering (0-9)6
Prerequisite: Minimum of 15 credit-hours of Graduate Courses *Staff*

Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering or perhaps another department in the case of an interdisciplinary program, leading to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of systems engineering.

ENVIRONMENTAL STUDIES

Members of the Graduate Faculty

Charles R. Ott, *Assistant Professor of Civil Engineering and Director of Program;* B.S., M.S., Ph.D., University of Washington.

Eugene F. Barry, Jr., *Assistant Professor of Chemistry;* B.S., Villanova University; Ph.D., University of Rhode Island.

Jesse Y. Harris, *Professor and Chairman of Department of Radiological Sciences;* B.S., M.S., Ph.D., Rutgers University.

Charles J. Higgins, *Professor of Chemical Engineering;* B.S., Massachusetts Maritime Academy; B.S., Lowell Technological Institute. P.E.

John C. Mallett, *Assistant Professor of Biology;* B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.

James A. Mann, *Associate Professor of Chemical Engineering;* B.S., Rensselaer Polytechnic Institute.

Master of Science Degree Program

This interdisciplinary program leads to a degree of Master of Science in Environmental Studies. It provides the students with (a) an overview of the entire area of environmental problems, including engineering, social, political, and economic problems, and (b) a concentration in one of several fields of interest of his choice.

A graduate of this program will find applications for his training with Federal agencies, local and state governments, consulting firms in the field of environmental control, or in industries which have environmental problems. The departments of Biological Sciences, Chemistry, Chemical Engineering, Civil Engineering, Radiological Sciences and Social Sciences all contribute to this program. A wide variety of courses is available to the student in the form of technical electives.

The program is open to qualified students in any of the engineering disciplines and in the biological or physical sciences. A Bachelor of Science Degree in a scientific or engineering discipline is required. Other qualified students may be admitted provisionally with the approval of the chairman of the Department of Chemical Engineering. Deficiencies in required course background may be made up while in the program.

Degree Requirements

Because of the diversity of background of students entering this program, it is frequently necessary for the student to make up deficiencies in his background by taking non-credit courses. Normally these courses will include basic instruction in analytical procedure, both chemical and physical, an introduction to biology, and

possibly an introduction to flow of fluids. Courses required for makeup of deficiencies will be determined by the Department Chairman.

Requirements for graduation will include the following:

1. A minimum of 32 credits in Seminar, required core courses, electives, and thesis.
2. 18-601 Environmental Studies Seminar (1-0) (1-0)2
3. 18-701 Graduate Research in Environmental Studies. (0-9) (0-9)6

Required Core Courses

18-510	Water Resources Management	(3-0)3
18-522	Solid Waste Management	(3-0)3
18-523	Air Resources Management	(3-0)3
18-528	Social Ecology	(3-0)3

Technical Electives

In general technical electives may be chosen from any graduate level course in Chemistry, Biology, Civil Engineering, Chemical Engineering, Radiological Health or Nuclear Engineering. All technical electives must have the approval of the Department Chairman.

Thesis

Each student will be required to undertake a six semester hour thesis. Students will choose a thesis advisor from a member of the staff approved by the Department Chairman and two associate advisors at least one of whom must be a member of the University of Lowell staff.

The student will be required to submit a proposal for his thesis to the Department for approval. Once the thesis is underway brief monthly reports are required to the thesis advisors and to the Chairman of the Department showing the progress of the thesis. Students are required to make a presentation of their thesis proposal and accompanying data at a Seminar Meeting and another presentation to another Seminar when the thesis is completed and ready to be defended.

All students will defend their theses when completed in accordance with Graduate School regulations.

Courses of Study

10-510 Water Resources Management **(3-0)3**

Staff

A study of all actual and potential sources of potable and industrial waters is made with particular attention given to the origin, chemical composition and possible sources of contamination. Water

purification methods are studied in detail including reclamation of saline waters, especially from a chemical engineering standpoint. Economic factors in purification in water distribution are also investigated.

18-512 or 513 Environmental Economics **(3-0)3**

Staff

Investigation is made of a number of environmental contamination problems, examining the sources of contamination, methods of control and cost of such control. Costs are compared with severity of governmental regulations. Direct and indirect costs are evaluated from the short term and long term viewpoint, with particular reference to changes in costs of products, tax structure, and return on investment. Impact of governmental regulations on the cost of interrelated products is studied in some detail.

18-519 Environmental Regulations and Controls **(3-0)3**

Staff

A general review is made of the federal, state and local environmental regulations and controls. Frequency of controls and required monitoring systems are also discussed in some detail. Possible legal sanctions against violators are examined together with their potential impact on the environmental system.

18-520 Environmental Impact Statements **(3-0)3**

Staff

Since any new activity requires an Environmental Impact Statement, it is important that a methodology be developed for preparing environmental impact statements. This course deals with the information required and methods of writing environmental impact statements for both the federal government and for state agencies. Current and future review systems are investigated.

18-522 Solid Waste Management **(3-0)3**

Staff

A detailed study is made of the various sources of waste and pollution from municipal, industrial, and other sources. An analysis of the various types of solid waste is made with an evaluation of methods of separation and possible recycling. Current technology of solid waste handling, including incineration, landfill and recycling are studied in detail. Economics of the various processes are discussed.

18-523 Air Resources Management **(3-0)3**

Staff

This course emphasizes the problems involved in air pollution and the technologies developed for its control. Methods of analysis and technology of removing gaseous contaminants and particulate solids from waste gas streams are emphasized. The chemical engineering aspects of these techniques constitute a major portion of the course. Economics of removal of contaminants is also emphasized.

18-527 Environmental Laws **(3-0)3**

Staff

The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protective Agency and the Occupational Safety and Health Acts, are studied in detail. Local laws and ordnances are discussed where pertinent. Legal procedures in handling complaints and court procedures are examined in detail.

18-528 Social Ecology **(3-0)3**

Staff

This course provides the student with an exposure to man's interrelationship with his total environment and its effects on social behavior. Political, social and economic responses to environmental laws and the overall problem of conformance to laws is discussed in a seminar-type atmosphere.

18-529 Land Use Management **(3-0)3**

Staff

All aspects of the new technologies of land use management are explored in detail. The function of regional planning boards and overall state planning of land use are also investigated. Alternative uses of land including the economics, political, social and ecological aspects are discussed in considerable detail.

18-651 Special Topics in Environmental Studies **(3-0)3**

Staff

The course allows students to investigate in depth the various aspects of the environmental field. This is usually an individual effort and term papers are required covering the work done by the student. Generally speaking, these topics are supervised by a specific member of the Staff.

MECHANICAL ENGINEERING

Members of the Graduate Faculty

William T. Hogan, *Professor of Mechanical Engineering,* B.S., Northeastern University; S.M., D.Sc., Massachusetts Institute of Technology.

C. Zelman Kamien, *Associate Professor of Mechanical Engineering;* B.S., M.S., Ph.D., Purdue University.

Jon R. Kelly, *Professor of Mechanical Engineering;* B.S., Northwestern University; S.M., Sc.D., Massachusetts Institute of Technology.

Bernard J. Korites, *Assistant Professor of Mechanical Engineering;* B.S.M.E., Tufts University; M.Eng., Yale University; Ph.D., Tufts University.

John A. McElman, *Associate Professor of Mechanical Engineering;* B.S.M.E., M.S.M.E., Northeastern University; Ph.D., Virginia Polytechnic Institute.

Kun Min, *Associate Professor of Mechanical Engineering;* B.S., Lehigh University; M.S.E., University of Michigan; Ph.D., University of Illinois.

Alan Mironer, *Professor of Mechanical Engineering;* B.M.E., Rensselaer Polytechnic Institute; M.Eng., Yale University; Ph.D., Syracuse University.

Ronald P. Murro, *Associate Professor of Mechanical Engineering;* B.C.E., Cooper Union; M.S., Sc.D., Columbia University.

Eugene E. Niemi, Jr., *Assistant Professor of Mechanical Engineering and Chairman of the Department;* B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D., University of Massachusetts.

John C. O'Callahan, *Assistant Professor of Mechanical Engineering;* B.S., M.S., Ph.D., Northeastern University.

Steven Serabian, *Associate Professor of Mechanical Engineering;* B.S., Rensselaer Polytechnic Institute, M.S., Union College.

G. Dudley Shepard, *Professor of Mechanical Engineering,* B.S., Yale University; S.M., Sc.D., Massachusetts Institute of Technology.

Master of Science Degree Program

The Department of Mechanical Engineering offers two programs leading to the Master's degree. The thesis program consists of a total of at least thirty semester hours of work including a thesis of at least six semester hours credit. The non-thesis program consists of at least thirty-three semester hours of course work which must include three credits of 22-701 or 22-702, Graduate Research in Mechanical Engineering. This non-thesis program is offered only to students who have already had experience equivalent to the thesis experience and who petition for a non-thesis program.

Prior to his or her first graduate registration, each candidate for the degree will be interviewed by representatives of the graduate faculty for the purpose of assigning an advisory committee. The

advisory committee will work with the candidate to outline a program of course work which will fit his specific needs and goals. The candidate is required to submit a thesis proposal which must be approved by his advisory committee prior to initiating a thesis research.

The program of each candidate is subject to review and revision at any time and may be modified to take account of the availability of specific courses, changes in the student's needs and goals, or for other good reasons, as determined by the student's advisory committee.

Courses of Study

22-521 Mechanical Behavior of Materials **(3-0)3**
Prerequisite: 22-475 *Murro*
An examination of deformation mechanisms in solids and the study of such topics as brittle and ductile modes of fracture, fatigue, creep, viscoelasticity, diffusion, friction and wear using actual case studies of failures.

22-530 Ultrasound, A Nondestructive Evaluation Method **(2-3)3**
Serabian
Propagation characteristics of ultrasound are developed and analyzed to indicate usefulness as a nondestructive method of evaluation. Equipment for generation, detection and display. Scientific and engineering applications using velocity and attenuation measurements are stressed.

22-531 Advanced Thermodynamics **(3-0)3**
Hogan
A comprehensive treatment of the classical first and second law. Availability, criteria of equilibrium, heterogeneous systems, mixtures and solutions, chemical equilibrium. Introduction to statistical methods as applied to evaluation of thermodynamic properties.

22-534 Transport Processes **(3-0)3**
Kelly
Diffusive and convective transport of mass, momentum and energy. Forced convection in laminar and turbulent flows. High velocity flows, ablation, condensation, drying, combustion of solids and liquids.

22-535 Advanced Heat Transfer **(3-0)3**
Offered alternate years *Min*
Heat conduction: analytical and numerical solutions. Thermal

stresses. Laws of thermal radiations. Combined modes of heat transfer. Heat transfer in the environment and in biological systems. Thermal pollution.

22-536 Combustion **(3-0)3**

Min

Dynamics of premixed and diffusion flames. Ignition and extinction. Burning of liquid and solid fuels. Radiation from flames. Fire problems.

22-541 Advanced Fluid Mechanics **(3-0)3**

Offered alternate years *Mironer*

Basic equations of incompressible flow. Flow in open channels. Water waves. Flow over airfoil; lift and drag. Creeping flow and theory of lubrication. Boundary layer. Introduction to the statistical theory of turbulence. Experimental techniques.

22-542 Advanced Gas Dynamics **(3-0)3**

Offered alternate years *Mironer*

Equations of motion for inviscid, compressible fluid. One-dimensional steady flow with area change, friction, heat transfer and combustion. Shock waves. Unsteady flows and wave phenomena. Similarity characteristics, small disturbances, approximation procedures.

22-544 Acoustics **(3-0)3**

Offered alternate years *Korites*

Fundamentals of the propagation of sound in fluids and structures. Included will be a development of the basic concepts and equations and the application of these to special topics such as physiology, underwater acoustics and sound control.

22-546 Energy Conversion **(3-0)3**

Kamien

Concepts of thermodynamics pertaining to energy conversion; irreversible thermodynamics. Solid-state phenomena involved in conversion processes; energy forms, equations of states and energy fields. Selected topics in direct energy conversion systems.

22-548 Advanced Topics in Aerodynamics **(3-0)3**

Prerequisite: 22-483 or Permission of Instructor *Niemi*

Application of aerodynamic principles to three or four of the following topics: helicopter rotor aerodynamics (including propellers and wind turbines), rocket trajectories, orbital mechanics, aircraft per-

formance analysis, stability and control. Topics varied from year to year to suit current student interest.

22-551 Continuum Mechanics **(3-0)3**
Murro
Stress and deformation in a continuum in tensor notation. Fundamental laws of mechanics and thermodynamics. Applications to elastic, viscous and viscoelastic substances.

22-552 Structural Applications of Composite Materials **(3-0)3**
McElman
Study of constitutive relationships for anisotropic materials and application of these materials to structural elements such as beams, plates and shells. Problem areas considered include bending, buckling, and vibrations.

22-553 Finite Element Analysis **(3-0)3**
O'Callahan
A review of matrix algebra and calculus to develop the finite element equations in structural and thermal systems. Review of stress, strain and constitutive equations of solids. Develop mass and stiffness matrices for truss, frames, 2D and 3D solids. A large finite element computer program (SAPIV) will be used to solve problems in structural mechanics. Non steady heat conduction problems will also be studied using finite element techniques.

22-554 Theory of Elasticity **(3-0)3**
Prerequisite: 22-551 *McElman*
Offered alternate years
Formulation of the problem of elastic equilibrium. Torsion and flexure of prismatic bars, contact stresses, plane stress, plain strain and stress concentrations.

22-556 Theory of the Inelastic Continuum **(3-0)3**
Prerequisite: 22-551 *Murro*
Development of the constitutive equations governing inelastic (anelastic, viscoelastic, plastic and visco-plastic) deformations. Theorems and boundary value problems as applied to inelastic continua.

22-558 Plates and Shells **(3-0)3**
McElman
Variational methods are utilized to derive the plate and shell equilibrium equations including nonlinear effects and inertia terms. So-

lutions to bending, buckling and vibration problems are obtained for rectangular and circular plates. The membrane theory of shells as well as the general theory is investigated and solutions are obtained for a variety of practical shell problems.

22-562 Advanced Dynamics (3-0)3
McElman
Dynamics of mechanical systems by use of direct and variational methods. Three-dimensional rigid body dynamics and vibrations of lumped parameter and continuous systems. Non-linear and self-excited oscillations. Stability.

22-564 Structural Dynamics (3-0)3
O'Callahan
Review of matrix operations, development of the equations of motion of a single and multi degree of freedom systems. Development of stiffness, mass and damping matrices. Condensation of equations by stiffness condensation and GUYAN reduction. Modal analysis techniques to encouple equations of motion. Direct integration of the motion equations. Discussion of proportional and non-proportional damping. Applications using computer programs such as EIGENV and SAPIV to solve problems in structural dynamics.

22-601 Seminar in Mechanical Engineering (1-0) (1-0)2
Prerequisite: Permission of Department *Staff*
Discussion by staff members and students of current technical publications research and topics of general interest in mechanical engineering.

22-651 Selected Topics in Mechanical Engineering (3-0) (3-0)6
Staff
Advanced topics in the various fields of mechanical engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary mechanical engineering.

22-701 Graduate Research in Mechanical Engineering (0-9) (0-9)6
Prerequisite: Permission of Advisor *Staff*
Introduction to the methods of contemporary mechanical engineering research. Open only to students who are concurrently engaged in thesis or project research.

22-751 Advanced Projects in Mechanical Engineering (0-3) (0-3)2
Prerequisite: Permission of Department *Staff*
Independent reading and investigation of a particular topic of current interest in mechanical engineering.

NUCLEAR ENGINEERING

Members of the Graduate Faculty

Gilbert Brown, *Instructor of Nuclear Engineering,* B.S., Cornell University, S.M., Nucl. Eng., Ph.D., Massachusetts Institute of Technology.

William L. Filippone, *Assistant Professor of Nuclear Engineering,* B.S., University of Notre Dame, Ph.D., University of Maryland.

James P. Phelps, *Adjunct Associate Professor of Nuclear Engineering, Reactor Engineer, and Chairman of the Department,* B.S., University of Maine, Ph.D., Michigan State University.

Edward E. Pilat, *Adjunct Associate Professor of Nuclear Engineering,* B.S., Cornell University, S.M., Ph.D., Massachusetts Institute of Technology.

Facilities and Areas of Research

The Nuclear Center houses major engineering research facilities. A 5-MeV Van de Graaff accelerator is currently in operation and a 1-Mw Swimming-pool research reactor is now operating on-line. An on-line PDP-9 computer with 32K word core memory and a Foreground/Background operating system supports the Nuclear Center research activities.

Research is being conducted in such areas as: fast neutron cross section measurements, fast reactor shielding and heterogeneity effects, pulsed fast neutron experiments, simplified solutions of the neutron transport equation, development of two-dimensional response matrix methods, radiation damage and radiation induced creep in metals and reactor decommissioning.

Master of Science Degree Program

The graduate program in Nuclear Engineering offers professional training at the master's degree level designed to provide the opportunity for the student to broaden and deepen his knowledge of nuclear engineering problems. Participants in the program, will follow an elective program which is guided and approved by the Graduate Committee. A minimum of 30 credit hours is required with a minimum of 18 and a maximum of 24 credit hours in course work, and a minimum of 6 and a maximum of 12 credit hours for thesis research. There are no formal foreign language requirements for the Master of Science degree in Nuclear Engineering. Undergraduate subjects may be required of students who are deficient in their prior training. Each student must continue to have satisfactory performance in both course and thesis work. In formal courses, satisfactory performance is defined as a grade of B or better in each course. No more than two C's may be used for an advanced degree. The thesis must be defended in an oral examination conducted by the student's thesis committee which will be composed of the thesis

advisor and at least two other Members or Associates of the Graduate Faculty.

A core curriculum consisting of 24-505-506 Reactor Physics and 24-507-508 Reactor Engineering is required of all students who are candidates for the Master's degree in Nuclear Engineering. These core courses together with other Nuclear Engineering courses acceptable for fulfilling degree requirements are listed below. In addition, elective courses from the departments of Radiological Sciences, Physics, Mechanical Engineering and Mathematics may be approved for degree credit by the Graduate Committee.

Courses of Study: Core Curriculum

24-505 Reactor Physics **(3-0)3**
Filippone

Review of nuclear physics, cross sections, fission; the neutron transport equation; diffusion theory; one-speed reactors; reactor kinetics, variational methods; perturbation theory.

24-506 Reactor Physics II **(3-0)3**
Prerequisite: 24-505 *Filippone*

Numerical methods; reactor control, rod worths, self-shielding, fuel depletion, fission product poisoning; the multigroup method; slowing-down calculations, Fermi age theory.

24-507 Reactor Engineering I **(3-0)3**
Brown

Analysis of fission energy generation and transport in a reactor. Analytical and numerical analysis of heat transfer in nuclear reactors; fluid dynamics.

24-508 Reactor Engineering II **(3-0)3**
Prerequisite: 24-507 *Brown*

Continuation of 24-507. Analysis of reactor power cycles and detailed discussion of the characteristics of different reactor types.

Elective Courses

24-404C Reactor Design **(3-0)3**
Prerequisites: 24-301, 24-401 *Brown*

A group design project in which the class participates in the overall design of a nuclear power plant system, integrating the requirements of reactor physics, control, heat transfer, thermodynamics, fuel cycle, economics, safety, siting and radiological and environmental effects. Each member of the class will be responsible for a particular aspect of the design.

24-509 Fast Reactors **(3-0)3**
Prerequisite: 24-302 or 24-506 *Staff*
General characteristics of fast reactors. Breeding cycles and plutonium production; neutron balance, breeding ratio and doubling time. Simplified methods for fast reactor calculations. Kinetics, control and safety of fast reactors; sodium void and doppler coefficients. Engineering consideration and design concepts in large, fast power reactors.

24-510 Nuclear Fuel Cycle and Power Economics **(3-0)3**
Prerequisite: 24-302 or 24-506 *Brown, Forbes, Pilat*
Discussion of the nuclear fuel cycle, including preirradiation, irradiation and post-irradiation steps encountered by the fuel in a nuclear reactor. Evaluation of the components of the cost of electricity produced by a nuclear reactor.

24-601 Seminar in Nuclear Engineering **(1-0) (1-0)2**
Prerequisite: Permission of Department *Staff*
Discussion by staff members and students of current technical publications, research and topics of general interest in nuclear engineering.

24-651 Selected Topics in Nuclear Engineering **(3-0) (3-0)6**
Prerequisite: Permission of Instructor *Staff*
Advanced topics in the various areas of nuclear engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary nuclear engineering.

24-701 Graduate Research in Nuclear Engineering **(0-9) (0-9)6**
Prerequisite: Permission of Advisor *Staff*
Every graduate student in nuclear engineering is required to write a thesis which is based on the results of original research done under the supervision of a senior staff member.

24-751 Advanced Projects in Nuclear Engineering **(0-3) (0-3)2**
Prerequisite: Permission of Department *Staff*
An opportunity for individual study, under the direction of a staff member, of topics in or related to nuclear engineering.

PAPER ENGINEERING

Members of the Graduate Faculty

Higgins, Charles J., *Professor of Chemical Engineering,* B.S., Lowell Technological Institute, P.E. (Massachusetts)

Keeney, Norwood H., Jr., *Professor of Chemical Engineering and Acting Chairman of Department ;* B.S., Trinity College, Hartford; M.S., University of Maine, Ph.D., University of Manchester, England. P.E. (New Hampshire)

Mann, James A., *Associate Professor of Chemical Engineering;* B.S., Rensselaer Polytechnic Institute.

Walkinshaw, John W., *Assistant Professor of Chemical Engineering;* B.S., M.S., Lowell Technological Institute.

Master of Science Degree Program

This program provides for advanced study and research training in paper engineering and allied subjects, with specific application to the paper industry.

The Paper Engineering Department will consider applicants in the following categories:

1. Graduates of the University of Lowell Chemical Engineering (Paper Option) program.
2. Graduates in Paper Engineering or Paper Technology from other universities.
3. General B.S. or M.S. graduates in engineering or chemistry with no previous training in paper engineering.

Requirements for the M.S. Degree in Paper Engineering

1. 21-701-702 Research up to 6 credits
2. 21-601-602 Paper Engineering Seminar (1-0) (1-0)2
3. A minimum of 12 credits in paper engineering subjects chosen from the courses of study outlined below.
4. A minimum of 12 credits in approved technical electives.
5. A minimum of 30 credits in thesis, paper engineering and technical electives is required to fulfill the requirements of a Master's Degree in Paper Engineering.
6. Additional undergraduate subjects may be required of students who have deficiencies in their prior training. Technical electives must be approved by the Head of the Department of Chemical Engineering.

Each student shall enroll in seminar for 2 semesters and additionally during the period of thesis research.

Technical Electives

Any subject in chemistry in the 500 series.

Any subject in chemical engineering in the 500 series.

Thesis
Each student will be required to undertake a six semester hour thesis. All students will defend their theses when completed according to Graduate School regulations. During the period that the student is enrolled in graduate thesis he will be required to submit a brief monthly report to the staff of the Department showing progress of his thesis and approval by his advisor.

Courses of Study

10-404G Process Calculations of Paper & Pulp Processes (3-0)3
Prerequisite: Permission of Instructor *Keeney*
Mathematical analysis of various processes encountered in pulp and paper industry, using material and energy balances. Application of chemical Engineering principles to various operations.

21-503-504 Advanced Converting Processes (3-0) (3-0)6
Prerequisite: Permission of Instructor *Higgins, Mann*
Specific converting processes. Analysis of coating processes; Water-and solvent-based, extrusion and hot melts. Latest techniques used by the converting industry, involving mechanical and chemical operations. Engineering analysis of processes. Oral and written reports and plant visits.

21-505 The Physics of Paper (3-0)3
Prerequisite: Permission of Instructor *Keeney*
Structures of fibers from a fundamental viewpoint and their effect on strength and other properties of sheets made of these fibers. Comparison of cellulosic fibers and synthetic fibers. Engineering properties of fibrous materials.

21-506 New Techniques in the Paper Industry (3-0)3
Prerequisite: Permission of Instructor *Mann*
Lectures and discussions of new developments in engineering, design, and application of physical and chemical principles in the manufacture of paper products. Economic comparisons of new processes. Plant visits. Oral and written reports.

21-507 Fundamentals of Reprography (3-0)3
Prerequisite: Permission of Instructor *Mann*
An in-depth study of replicating and imaging systems from carbon paper, to xerography, to halography, covering theory and principles of operation, design and development of hardware and supplies, typical specifications and a cursory economic evaluation of these systems. Because of the unique technical character of this new field,

a review of copyright, patents and trade secrets is provided. The current state of the art is reviewed and this potential represented by recent developments in the field is examined.

21-508 Advanced Paper Systems Analysis (3-0)3
Prerequisite: Permission of Instructor *Keeney*
Chemistry and engineering principles applied to non-fibrous components in paper-making. Discussion of alum chemistry, fillers and other additives.

21-509 Economics of the Paper Industry (3-0)3
Prerequisite: Permission of Instructor *Mann*
An evaluation of the paper industry from an economic viewpoint. Examination of costs and availability of different raw materials, additives and finishing materials. Analysis of competitive position of the paper industry and its products. Evaluation of foreign competition.

21-512 Advanced Fiber Processing (3-0)3
Prerequisite: Permission of Instructor *Keeney*
A study of fiber properties as related to fiber processing. Treatment of various theories of fiber processing. Discussion of mechanical treatments of fibers on the wet and dry properties of papers made from these fibers.

21-513 Non-cellulosics in the Paper Industry (3-0)3
Prerequisite: Permission of Instructor *Mann*
An analysis of the role of non-cellulosics such as glass and polymeric materials in the field of paper technology. Characteristics imparted to paper structures and economics will be evaluated.

21-516 Analysis of Paper Formation Process (3-0)3
Prerequisite: Permission of Instructor *Keeney*
Discussion of the variables and factors involved in the formation of the paper web. Consideration given to fiber flocculation and orientation and to head-box design.

21-520 Environmental Problems in the Paper Industry (3-0)3
Prerequisite: Permission of Instructor *Mann, Higgins*
An in-depth study of the technical and economic aspects of the problems of the paper industry as they relate to environmental impact. Review of current technologies and assessment of future developments required to fulfill governmental requirements of EPA, OSHA and other agencies.

21-601 Paper Engineering Seminar **(1-0) (1-0)2**
Staff

Required of all paper engineering graduate students.

21-651 Selected Topics in Paper Engineering **(3-0) (3-0)6**
Prerequisite: Permission of Instructor *Staff*
Advanced topics in the various fields of paper engineering. Contents may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary paper engineering.

21-701 Graduate Research in Paper Engineering **(0-9) (0-9)6**
Prerequisite: Permission of Advisor *Staff*
Every graduate student is required to write a thesis on original research work done under the supervision of a senior committee appointed by the Department Head.

21-751 Advanced Projects in Paper Engineering **(0-3) (0-3)2**
Prerequisite: Permission of Department *Staff*
Special projects laboratory undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by Department Head.

PLASTICS

Members of the Graduate Faculty

Aldo Crugnola, *Professor of Plastics and Chairman of Department;* A.B. Boston University; M.S. Northeastern University; Sc.D. Massachusetts Institute of Technology.

Rudolph D. Deanin, *Professor of Plastics;* A.B. Cornell University; M.S., Ph.D. University of Illinois.

Everett S. Arnold, *Associate Professor of Plastics;* B.S. Southeastern Massachusetts University; M.S., Lowell Technological Institute.

Russell W. Ehlers, *Professor of Plastics;* B.S., M.A. Wesleyan University; Ph.D. Yale University.

Clarence J. Pope, *Professor of Plastics;* B.S., Clemson University; M.S., Lowell Technological Institute.

Nick R. Schott, *Assistant Professor of Plastics;* B.S., University of California at Berkeley; M.S., Ph.D. University of Arizona.

Associates of the Graduate Faculty

Stephen B. Driscoll, *Assistant Professor of Plastics;* B.S., M.S., Lowell Technological Institute.

Stephen A. Orruth, Jr., Assistant Professor of Plastics; *B.S., M.S., Lowell Technological Institute.*

Raymond O. Normandin, *Professor of Plastics;* A.B., St. Anselm's College; M.S., Boston College.

Henry E. Thomas, *Professor of Plastics,* B.T.E. Lowell Technological Institute; P.E.

Master of Science Degree Program

The graduate program in plastics offers professional training at the Master of Science level designed to provide the opportunity for the study of more advanced plastics theory and practice, and to broaden the background of experienced members of the profession and to keep up with latest fundamental developments in the field.

Admission to the program is open to candidates with a B.S. in plastics or a related field. Candidates with degrees in chemistry or chemical engineering degrees from other schools or industrial experience in place of University of Lowell B.S. course in Plastics, will take the undergraduate courses they lack as prerequisites before undertaking the graduate courses in Plastics.

Each student is assigned a faculty advisory committee by the Department Head to provide guidance in the selection of courses and in the development of a study plan which will fit his specific needs and goals. When the study plan includes a thesis, the advisory committee also serves as thesis committee, with the director of

the thesis research project serving as the chairman of the committee. Normally, the chairman of the student's advisory committee is a member of the Plastics Graduate Faculty whose technical interests and research parallel those of the student. The membership of the student's committee may be changed as his area of specialty becomes more clearly defined.

A candidate for the degree of Master of Science in Plastics must complete either a thesis based on the results of original research; or a project which consists of scholarly investigation such as a review, synthesis, or design in the student's field. The Department Chairman, considering the needs of the student and the recommendation of the student's advisory committee, will determine whether the student should complete a thesis or a project. A proposal, which describes the nature and extent of the thesis or project that the student expects to complete, must be submitted to his advisory committee for approval.

A minimum of 30 semester-hours is required of all students who are candidates for the M.S. degree. These should include at least 12 semester hours of courses in plastics, two semester hours in plastics seminar, and not more than 12 semester hours in minor subjects in related departments. Students whose program includes a thesis may receive 6 to 12 semester-hours credit for this work; those whose program includes a project may receive up to three semester-hours credit for it.

Through proper choice of elective courses, the overall program leading to the Master of Science degree in Plastics can be specifically designed to meet the particular needs and goals of the individual students. The overall program of each student, including the thesis or project, must be approved by the student's committee, the Department Chairman, and the Dean of the Graduate School. Normally the program is formulated soon after the student is fully admitted into the Graduate School. This program is subject to review and revision at any time and may be modified to take into account the availability of specific courses, changes in the student's needs or goals, or for other good reasons.

Manmade Fiber Option

This more specialized course of study is designed to prepare prospective M.S. candidates for careers in the fiber producing, the fiber processing, and the fiber reinforced plastics industries.

Admission to the program is open to students with an undergraduate degree in plastics, textiles, or other applicable field of study (mechanical or chemical engineering, applied physics or chemistry). The student's faculty advisory committee will review his

individual background to determine any further necessary prerequisites.

The curriculum includes 16 units of common/core courses, 2 units of seminar, 8 units of suggested electives and a 6 unit thesis in an area of current interest to the synthetic fiber industries.

Subject Requirements (Exclusive of Thesis and Seminar)

Core Courses (16 Units)

97-503	Intro. Phys. Chem. Macromolecules	(3-0)3
97-505	Polymer Laboratory	(0-3)1
26-503	Mechanical Behavior Polymers	(3-0)3
26-504	Polymer Proc./Morphology/Properties	(3-0)3
26-515	Theory/Technology of Fiber Spinning	(3-0)3
26-525	Phys. and Chemical Proc. of Synthetic Fibers and Fiber Structures	(3-0)3

Elective Courses (8 Units)

26-506	Polymer Structure/Properties/Applications	(3-0)3
26-516	Reinforced Plastics/Composite Materials	(3-0)3
26-519	Polymer Characterization	(2-0)2
26-521	Polymerization Engineering	(3-0)3
26-526	Adv. Phys./Chem. Proc. Synthetic Fibers and Fiber Structures	(3-0)3
26-527	Knitted Structures	(2-3)3
26-528	Non-Conventional Fiber Structures	(2-3)3
26-529	Fiber Evaluation	(2-3)3
26-530	Intro Fiber Market/Management/Plant Organization	(3-0)3

Courses of Study

26-502 New Plastics Processing Techniques (3-0)3

Schott

Critical examination of new plastics processing techniques appearing in the research literature and being commercialized in the plastics industry.

26-503 Mechanical Behavior of Polymers (3-0)3

Crugnola

Mechanical properties of bulk polymers as a class of engineering materials. The relation between the chemical/physical structure of polymers and their utilization as plastics, fibers and elastomers. The effect of molecular weight, molecular weight distribution, branching, cross-linking, order and crystallinity of bulk properties. Linear visco-elasticity and its application to creep, relaxation, dynamic and stress/strain response phenomena. The principles and the formula-

tion of time/temperature superposition. The thermodynamic and statistical mechanics view of rubber elasticity. The failure behavior of polymeric materials and its interpretation on the molecular level.

26-504 Processing, Morphology, and Properties **(3-0)3**
Prerequisite: 26-503 *Crugnola*
Effect of processing conditions on polymer fine structure and morphology, and the attendant changes in mechanical and physical properties. Theoretical interpretation of the interrelationships involved.

26-506 Polymer Structure, Properties, and Applications **(3-0)3**
Deanin
The fundamental relationships between molecular structures, properties, and end-use applications of plastics materials will be explored in detail. Molecular structural features include chemical composition, molecular size and flexibility, intermolecular order and bonding and supermolecular structure. Properties include processability; mechanical, acoustics, thermal, electrical, optical, and chemical properties; price and balance of properties. Applications include rigid solids, flexible solids, foams, films, and non-plastics applications.

26-507 Plastics Industry Organization **(3-0)3**
Deanin
Economics of producing plastics raw materials and converting them into end products, from research and development to plant construction, and marketing. Market analysis of plastics production, processing, and consumer patterns; commercial development, sales, and technical service. Organization of the plastics industry for research and development, specialty and commodity production, profit, and growth.

26-509-510 Plastics Processing Theory **(3-0) (3-0)6**
Schott
Principles of heat transfer, rheology, mixing, crystallization, and chemical reactions involved in the processing of plastics, and their applications to plastics process engineering.

26-511 Multiphase Polymer Systems **(3-0)3**
Deanin
Compatibility of polymer blends, block and graft copolymers. Morphology of semicompatible systems, and theoretical relationships between structure and properties. Practical systems in development and production.

26-512 Plastics Foams **(3-0)3**

Deanin

Preparation, structure, and properties of plastics foams. Practical systems in development and production. Properties, applications, and markets for plastics foams and products made from them.

26-513 New Plastics Materials **(3-0)3**

Deanin

Critical examination of the new plastics materials appearing in the research literature and being field-tested for commercialization in the plastics industry.

26-515 Theory and Technology of Fiber Spinning **(3-0)3**

Schott

Principles and theory of rheology, heat and mass transfer associated with the forming operations in melt and solution spinning of fibers. The equations of motion, continuity and energy are used to formulate the analytical description of fiber spinning. Applications of the theory are discussed in terms of equipment and practices of the synthetic fiber industry.

26-516 Composite Materials **(3-0)3**

Crugnola

The potential of composites as a class of materials, and the uniqueness of the mechanical/physical properties realizable. Fundamental concepts underly those properties, with particular emphasis on fibrous reinforced plastics. Survey of matrices, reinforcements, and prediction of composite properties from a knowledge of properties and topology of constituent materials. Factors affecting ultimate strength and fatigue behavior.

26-518 Product Design **(3-0)3**

Deanin

Theoretical principles and sound engineering practice involved in the design of new end products made from polymers, applying the total systems approach to the balance between product design, choice of materials, and process technique, as they affect competitive choice for commercial success.

26-519 Polymer Characterization **(2-0)2**

Crugnola

Survey of the leading physico-chemical techniques for characterizing the composition, structure, and morphology of polymer molecules and polymer systems.

26-521 Polymerization Engineering **(3-0)3**
Deanin, Schott
Engineering design of equipment and plants for polymer production. Processes for production of each of the major commercial polymers.

26-523 Material and Energy Balances in Plastics Processing **(3-0)3**
Schott
Batch and continuous processes. Dimensional analysis. Thermodynamic properties of thermoplastics. The use of enthalpy diagrams in energy balances. Heat capacity, sensible heat, heat of fusion, and heat of reaction. Intensive and extensive properties of plastics. Phase changes and transitions in thermoplastics.

26-524 Process Analysis, Instrumentation, and Control **(3-0)3**
Schott
Industrial instruments for measurement and control of plastics processes. Design of experiments. Analysis of plastics forming operations. Dynamic testing techniques. Automatic plastics process control. Modeling and process simulation in extrusion and injection molding. Data acquisition systems.

26-525 Physical and Chemical Processing of Synthetic Fibers and Fiber Structures **(3-0)3**
Pope/Arnold
An introduction to systems utilized in the processing of synthetic fiber structures. These include drawing, winding, texturing, staple fiber production, blending, static control, dyeing and finishing. The effect of these mechanical, physical, and chemical processes on the resultant fiber and fiber structure behavior.

26-526 Advanced Physical and Chemical Processing of Synthetic Fibers and Fiber Structures **(3-0)3**
Pope/Arnold
A continuation of 26-525 to include a more detailed view of the processes and effects involved.

26-527 Knitted Structures **(2-3)3**
Arnold
A study of the principles of knitting and the mechanisms required to develop various fabric structures.

26-528 Non-conventional Fiber Structures **(2-3)3**
Pope
Nonwoven materials and unusual fiber structures such as needle-punched stitch bonded and ultra-sonic welded structures. Problems

are assigned for laboratory evaluations and written reports as well as oral presentations are required.

26-529 Fiber Evaluation **(2-3)3**
Pope/Arnold
Basic mechanical tools, techniques and their utilization by industry for research development, production control and end use evaluation. Moisture equilibrium and rates of change relations; basic fiber, yarn and structure dimensions; and an introduction to the determination and evaluation of the stress-strain-time properties of fibers and fiber structures; wear and abrasion are among the topics considered.

26-530 Introduction to Fiber Marketing, Management and Plant Organization **(3-0)3**
Arnold/Pope
An introduction to basic principles in the marketing, management, and plant organization of synthetic fibers. Consideration of distribution channels, costing, sales forecasting, management recruiting and machinery layouts.

26-531 Survey of Synthetic Fibers and Fiber Structures **(3-0)3**
Pope/Arnold
General discussion of the basic problems encountered in the synthetic fiber industries, including fiber and fiber structure properties, processing, utilization and various aspects of current research. Recent advances and projected developments.

26-543 Survey of Plastics Materials **(3-0)3**
Not open to B.S. Plastics *Normandin*
Descriptive course centering on the historical development of polymeric systems, their synthesis, structure, properties, and applications. Included will be a brief discussion on the typical additives employed to make plastics molding compounds.

26-544 Plastics Processing **(3-0)3**
Prerequisite: Permission of Instructor *Ehlers*
A theoretical and practical review study of plastics engineering techniques. Correlation of composition, processing and fabrication with mold, product and equipment design.

26-545 Methods of Experimental Analysis **(3-0)3**
Prerequisite: Permission of Instructor *Thomas*
Methods of efficient design and analysis of scientific and industrial processing experiments. Classical vs. factorial experiments, statistical distributions and statistical inference, single and multifactorial analysis, interaction, correlation and regression.

26-583 Research Methodology **(3-0)3**
Pope
A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving and student presentation of data are stressed. Extensive reading of research papers, analysis of such, and defense of the analysis is required.

26-601 Plastics Seminar: Literature Searching **(1-0) (1-0)2**
Staff
Survey of the technical literature in plastics, and techniques for searching it. Each student will carry out one literature research project per semester and report it to the class.

26-603 Plastics Seminar: Current Journal Literature **(1-0) (1-0)2**
Prerequisite: Permission of Department *Staff*
Survey of the technical journals which carry reports of current advances in plastics science and engineering. Each student will report to the class on a portion of the current journal literature.

26-605 Plastics Seminar: Research **(1-0) (1-0)2**
Prerequisite: Permission of Department *Staff*
Reports and discussions on current research in the department. Faculty and students will take turns presenting their current research activity, and turn to group discussion for guidance in solving their problems and planning their future work.

26-651 Selected Topics in Plastics **(3-0) (3-0)6**
Prerequisite: Permission of Instructor *Staff*
Advanced topics in the various fields of plastics. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary plastics.

26-701 Graduate Research in Plastics **(0-9) (0-9)6**
Prerequisite: Permission of Advisor *Staff*
Individual research projects in plastics chemistry, properties, processing, products, and industry organization.

26-751 Advanced Projects in Plastics **(0-3) (0-3)2**
Prerequisite: Permission of Department *Staff*
Special projects undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by Department Head.

COLLEGE OF HEALTH PROFESSIONS

Gertrude Barker, R.N., B.S., M.S., Ed.D., Dean

MASTER OF SCIENCE IN GERONTOLOGICAL NURSING

Members of the Graduate Faculty

May Futrell, *Associate Professor of Nursing;* B.S., M.A., Columbia University; Certificate, University of Southern California; Ph.D., Brandeis University.

Mona Hull, *Associate Professor of Nursing;* A.B., Mt. Holyoke College; M.N., Yale University; C.A.G.S., Ph.D., Boston University.

Description of Program

Gerontological Nurse Practitioner Program

Philosophy of the Graduate Program

The philosophy of the graduate program preparing the Gerontological Nurse Practitioner is based upon the philosophy of the University of Lowell and the nursing program of the College of Health Professions. The faculty believes that Master's level education focuses on specialization, research and leadership preparation.

Health care for the elderly should improve the quality of life rather than the mere lengthening of the life span. The faculty places high value on promoting positive attitudes toward the aged and aging. Accordingly, the Master's program will emphasize those knowledges and skills which are unique to meeting the health care needs of this population in a rapidly changing technological, economic and sociocultural environment. The faculty believes that the advancement of practice in gerontological nursing is achieved through the synthesis of specialized knowledge, applied theory, and expanded skills.

Expected Outcomes of the Program

Each student upon completion of the program of study is expected to:

1. Synthesize knowledge from gerontology, the behavioral and natural sciences for the purpose of developing theories for gerontological nursing practice.
2. Apply and evaluate theories in the application of nursing process to the care of the aged and aging population.
3. Expand functional competencies, specifically in the area of history taking, physical assessment and health care management of well and sick elderly.
4. Evaluate effectiveness of community services designed to

meet the needs of the aged and aging population and use appropriate resources to initiate change.

5. Promote positive attitudes toward the elderly and the aging population.

6. Collaborate with consumers and other health disciplines in matters of health care and social policy legislation.

7. Assume a leadership role that includes accountability and responsibility for improvement of health services to the aged.

8. Utilize research methodology to advance the practice of Gerontological Nursing.

9. Propose alternative solutions to problems in the delivery of health care to the elderly as a result of investigatory studies.

10. Generate new knowledge in gerontological nursing as a result of research activities.

11. Assume responsibility for ongoing education and enlightenment for professional and personal growth.

Entrance Requirements

To be admitted to the Graduate Program, a student must hold a bachelor's degree in nursing from a National League for Nursing accredited collegiate program and be licensed to practice nursing in the Commonwealth of Massachusetts. The applicant must submit official transcripts of all previous work, undergraduate and graduate, which shall be at least a 3.0 cumulative grade point average. Prerequisite to admission is successful completion of a course in Introductory Statistics.

In addition to meeting these minimum standards, the student should submit test results from either the Miller Analogy test or the Graduate Record Examination, three letters of recommendation (one from an employer) and a letter stating his interest and future goals as these relate to the health care of the elderly. It is also recommended that the applicant have practiced professional nursing for at least two years after graduation.

It is the policy of the University of Lowell to accept all students without regard to race, color, or national origin. Priority for enrollment will be given to nurses who are already working with the aging and the aged in an agency or institution committed to meeting the health needs of this population.

Degree Requirements

Credits

A minimum of 39 credit hours of course work will be required of all students enrolled in the program. Each student shall complete three semesters within the calendar year. The third semester is a 12 week summer session. There are no formal language requirements or

comprehensive examination requirements. A project which will consist of a scholarly investigation or a thesis is required for graduation.

Curriculum

The curriculum is divided into three interrelated segments: cognates, nursing theory and clinical experience.

The sequential order of the curriculum is planned to produce breadth and depth of cognitive, theory, and practice elements in each semester while showing progress from dependent to independent and interdependent nursing practice. The first semester introduces new knowledge, theories and practice in Gerontology and Gerontological Nursing.

The second semester involves continued practice in clinical settings under preceptorship. The theoretical foundations of leadership and psycho-social change are emphasized. A course in research in nursing offers exposure to research methodology and research design.

The final semester, the 12 week summer session, provides an intensive and continuous practice experience in Gerontological Nursing under one-to-one preceptorship. Experiences in collaboration with consumers and other health disciplines are provided. The student completes a research study in Gerontological Nursing. An elective provides opportunity for individual growth in a selected area.

Semester I		
35-550	Biomedical Aspects and Pathophysiology of Aging	3
33-610	Gerontological Nursing Theory I	6
33-613	Practicum in Gerontological Nursing I	4
	Total	13
Semester II		
47-551	Psychosocial Aspects of Aging	3
33-611	Gerontological Nursing Theory II	4
33-614	Practicum in Gerontological Nursing II	4
33-553	Research Design and Methodology	3
	Total	14
Semester III		
33-612	Gerontological Nursing III: Applied Theory and Practicum	6
33-701	Advanced Research in Gerontological Nursing	3
Elective		3
	Total	12

Summary of Subject Areas

1. Gerontological Nursing	24
2. Research in Nursing	6
3. Supporting courses	
a. Biomedical Aspects	3
b. Psychosocial Aspects	3
c. Elective	3
Total	39

Courses of Study

Semester I

35-550 Biomedical Aspects and Pathophysiology of Aging **3**
Class 48 Hours *Staff*

Study of various biological and pathophysiological factors of health and disease in the aging process using the systems approach. This course covers biological theories of aging; the effect of aging on the physiology of man; the natural history of aging; aging at the cellular and tissue level; genetic components of longevity; and molecular and chemical mechanisms of aging. Altered regulatory mechanisms as related to the aging process at the cellular, tissue and organ level are studied.

33-610 Gerontological Nursing Theory I **6**
Class 96 Hours *Staff*

Designed to synthesize: 1) knowledge of normative aging process; 2) knowledge of pathological factors involved in aging; 3) theories fundamental to advanced gerontological nursing practice; and to apply research theories to practice by utilizing the nursing process. The following theoretical areas are included: nursing process, systems theory, theories of aging, change theory, crisis theory, stress and adaptation, communications theory, economic and political theories, philosophy, leadership, role theory, legal aspects and pharmacodynamics. The student explores in depth the organization of health services and health practices in the community, and studies the forces (self, family, community) which influence health and illness in the aged population. Periodic reports, analyses of selected legislative, political, social and economic trends and issues which influence community health comprise some of the course requirements.

33-613 Practicum in Gerontological Nursing I **4**
Clinical Practice 128 Hours *Staff*
(8 hours per week for 16 weeks)
Concurrent with the didactic sessions is a planned continuous practicum experience in the health care of the aged in learning laboratories, ambulatory care centers, homes and community agencies serving the elderly, under the preceptorship of physician and nurse practitioners. The course includes history taking, physical assessment and the appraisal and management of client health in a problem oriented context. Students participate in learning laboratories and a Senior Citizens' Ambulatory Clinic organized by the faculty in cooperation with community nursing groups as well as community agencies serving the elderly. Leadership and role theories are applied during the patient management experiences.

Semester II

47-551 Psychosocial Aspects of Aging **3**
Class 48 Hours *Staff*
Analysis of current social gerontological literature (theory and research) pertaining to psychological and social variables over the adult life span. Primarily substantive concepts will be treated, including analysis of age stratification, age norms, socialization to old age, status of the aged, alienation and age, power and age, and age-stratum consciousness. The course covers the changes in behavior that occur from adulthood to old age, with special emphasis on changes in personality, mental and physical health, sensation and perception, intelligence, and learning. Particular attention is given to distinctions between normal and pathological changes which occur with aging.

33-611 Gerontological Nursing Theory II **4**
Class 64 Hours *Staff*
This course builds on knowledge and theories identified in the previous semester with direct application in the clinical area and further defines responsibilities for patient management in solving common health problems of the aging population. Theories of rehabilitation, both physical and mental, are emphasized in the care of the elderly client. All of the above lead to independent and interdependent decision making which enables the student to demonstrate in clinical practice the role responsibilities and leadership functions of the Gerontological Nurse Practitioner. Through the utilization of research studies, the student proposes alternative solutions to problems in the delivery of health care to the elderly.

33-614 Practicum in Gerontological Nursing II **4**
Clinical Practice 128 Hours *Staff*
(8 hours per week for 16 weeks)
Clinical experiences take place in ambulatory health care centers, health screening clinics, nursing homes and long-term institutions. In addition, a special experience in assessing needs of clients and discharge planning from acute hospitals in collaboration with social workers, physicians and nursing home administrators takes place under the preceptorship of nurse practitioners. Experiences in organization, leadership and evaluation of therapeutic psychosocial groups is offered at a long-term hospital.

33-553 Research Design and Methodology **3**
Class 48 Hours *Staff*
Study and discussion of research process as applied to the investigation and evaluation of nursing practice and education. Opportunities are provided for development of proposals for group and individual research.

Semester III

33-612 Gerontological Nursing III: Applied Theory and Practicum **6**
Seminar 32 Hours *Staff*
Clinical Practice 192 Hours
(16 hours per week for 12 weeks)
Students select clinical learning experiences aimed at strengthening their skills and consistent with their career goals. To encourage independent action, students may select specific gerontology clients, facilities and preceptors according to their needs. An expanded number of clinical hours has been planned so that students may have an intensive experience in functioning in the role of a Gerontological Nurse Practitioner. The student is expected to apply theory, demonstrate mature leadership and decision-making skills, and practice in an independent capacity as a participating colleague in collaborative health services. A weekly seminar centers around applied theory, problem-solving, issues in health care, role functions and evaluation of nursing action.

33-701 Advanced Research in Gerontological Nursing **3**
Staff
This course involves the completion of the independent study requirement for the Master's degree.* Students develop and test theory in Gerontological Nursing with emphasis on field experi-

*See Graduate Bulletin.

ments in primary health care settings. Also included is discussion of measurement and design problems, techniques of theory construction and statistical analysis.

COLLEGE OF MANAGEMENT SCIENCE

Members of the Graduate Faculty

Daniel E. Diamond, *Dean, College of Management Science; Professor of Economics;* A.B., University of Massachusetts; M.B.A., Boston University; Ph.D., New York University.

Jack D. Alexander, *Associate Professor of Management;* B.S., in B.A., M.A., M.A., University of Notre Dame; M.B.A., Harvard University; Ph.D., University of Notre Dame.

William J. Burke, *Professor of Accounting;* B.A., University of Massachusetts; M.Ed., Boston State College; J.D., Suffolk University.

Albert M. Cederlund, *Associate Professor of Economics;* A.B., Clark University; M.S., Columbia University; Ph.D., Clark University.

Leslie M. Dawson, *Professor of Management;* B.B.A., Iona College; M.A., University of Toledo; Ph.D., Michigan State University.

Gerald F. Downey, *Professor of Accounting;* B.A., M.B.A., Northeastern University; M.A., Ph.D., Boston College.

David B. Eastwood, *Assistant Professor of Economics;* A.B., Hanover College; M.A. Brown University; Ph.D., Tufts University.

Susan A. Goodwin, *Assistant Professor of Economics;* B.A., Wellesley College; M.A., Boston University; Ph.D., Tufts University.

Brooke Hargreaves, *Assistant Professor of Accounting;* B.A., Brandeis University; J.D., Northeastern University of Law.

Brackston Hinchey, *Associate Professor of Management;* A.B., M.A., Ph.D., University of Missouri.

Linda H. Kistler, *Professor of Accounting;* B.S. in B.A., M.S. in B.A., Colorado State University; C.P.A.

Goang-Tzer Liaw, *Assistant Professor of Management;* B.A., National Taiwan University; M.A., University of Minnesota; Ph.D., University of Illinois.

Thomas G. Macbeth, *Professor of Economics;* A.B., Cornell University; M.A., Ph.D., University of Southern California.

Stuart L. Mandell, *Commonwealth Professor of Management;* A.B., Brooklyn College; M.B.A., Syracuse University.

Carol C. McDonough, *Professor of Economics;* B.A., Marymount College; M.A., Ph.D., Boston College.

Martin Murphy, *Assistant Professor of Economics;* B.B.A., City College of New York; Ph.D., Boston College.

Santo J. Pullara, *Professor of Management;* B.S., M.B.A., J.D., Ph.D., Syracuse University.

Irwin A. Shapiro, *Associate Professor of Management;* B.S. in B.A., Syracuse University; M.B.A., Indiana University; Ph.D., Clark University.

Paul E. Snoonian, *Associate Professor of Economics;* B.S., M.B.A., Northeastern University; M.A., Ph.D., Michigan State University.

Associates of the Graduate Faculty

George C. Dery, *Associate Professor of Economics,* A.B., Merrimack College; M.A., Boston College.

Charles F. Feeney, *Assistant Professor of Accounting;* B.S. in B.A., Boston College; M.B.A., Northeastern University; C.P.A.

James C. Lillis, *Professor of Management;* B.S., Tufts University; M.B.A., Harvard University, P.E.

Charles F. Thompson, *Assistant Professor of Accounting;* B.S.A., Bentley College; M.B.A., Northeastern University; C.P.A.

George J. Toscano, *Professor of Accounting;* B.S., M.B.A., Northeastern University; C.P.A.

Louis E. Yelle, *Associate Professor of Management;* B.S., Lowell Technological Institute; M.S., M.B.A., Northeastern University.

Master of Management Science Program*

The graduate program in management has been designed to provide holders of non-management undergraduate degrees with an intensive program in modern, quantitative management techniques. The expectation is that people holding undergraduate degrees in engineering or the sciences would seek to achieve a thorough grounding in the various management core disciplines to enable them to handle managerial responsibilities in industry.

Admission to the MMS program is open to students with the appropriate undergraduate baccalaurate degree in engineering or pure and applied science. Applicants must submit with the graduate school application a transcript of the undergraduate degree and a GMAT (formerly ATGSB) score to be considered for admission. Generally, to be eligible for admission a student should have attained a 2.5 overall grade point average, or 2.75 in the junior and senior years, and a minimum score of 450 on the GMAT. Letters of recommendation are to receive a secondary role as admission criteria.

Part-Time Student Status

Students enrolled in less than the full program are considered part-time students. Part-time students have four years from the time the program is started to complete the program. Application for

*This program will be discontinued in 1976-1977. Please see the M.B.A. Program on page 124.

extension must be made if the program is not completed within four years.

Special Student Status and Admission to MMS Courses
Generally, there is no provisional admission to the MMS program. Applicants are either fully admitted or not admitted.

Special student status in the program is available only to graduate students at the University of Lowell in other curricula. Graduate students in other programs may be permitted to take up to two courses in the MMS program as special students if the courses can be used as electives in order to meet degree requirements. The electives cannot be an overload in the student's degree program; they must be a required part of the program. Students must have the necessary prerequisites for the courses selected.

Admission to courses in the MMS program is not open to undergraduate students.

Transfer Credits
Students may offer a limit of two acceptable courses taken prior to admission to the MMS program as transfer credits. After admission to the program students are expected to complete all courses at the University of Lowell and only under extenuating circumstances and with prior approval are students permitted to complete courses at other institutions. Typically, not more than two courses may be taken at other institutions, whether taken prior to admission or after. Approval for all transfer credit must be obtained from the graduate student advisor and from a University of Lowell instructor in the course(s).

Academic Grades
Graduate credit will be allowed for the MMS degree for grades A, AB, B, BC, and C. In order to qualify for the MMS degree, a student must successfully complete all courses with no more than two C grades; a student is ordinarily not allowed to repeat a course.

Grade Average Requirement
Upon completion of eight courses in the MMS program, students with a grade point average below 3.3 are required to pass a comprehensive examination administered by the CMS graduate faculty as a prerequisite to graduation.

The nature of the program provides for a prescribed curriculum. A regular full-time student who has completed six credit hours of the Principles of Economics at the undergraduate level would begin the program with the regular Fall semester. For students without the Economics credits, it is recommended to take 64 201-202 — Economics I and II — during the preceding Summer School.

All graduate courses will be offered during the hours of 4:00 to 8:00 p.m. This arrangement will facilitate part-time study.

Program
The program and sequence of courses are as follows:

Fall Semester:
60-540 Managerial Accounting
64-510 Economics of the Firm: Theory and Managerial Applications
64-511 Quantitative Analysis
66-551 Management of Human Resources

Spring Semester:
66-521 Marketing
66-531 Finance
66-571 Operations Research
66-572 Operations Management

Summer Session I
66-580 Business Problems and Policies
66-560 Business and Society

Summer Session II
Two Electives

Courses of Study

60-540 Management Accounting **(4-0)4**
Staff
This course is designed to provide an understanding of accounting as a tool for managerial decision-making. The fundamental structure of accounting including a conceptual approach to development of the Position Statement and Income Statements studied. Topics for discussion include analysis and interpretation of financial data, budgeting, funds flow, cash forecasting, cost analysis, breakeven analysis and cost control concepts. Business cases are used.

64-510 Economics of the Firm; Theory and Managerial Applications **(4-0)4**
Staff
An introduction to the tools and processes of microeconomic theory. The application of theoretical economic analysis to business problems through the construction of appropriate economic models.

64-511 Quantitative Analysis **(4-0)4**

Staff

This course is designed to utilize the mathematical and statistical skills of the graduate student and apply them toward the solution of management problems. Topics covered include random variables and their distributions, sampling theory, statistical estimation, hypothesis testing, analysis of variance, simple and multiple regression, correlation, and decision theory.

64-599 Graduate Seminar

Research in theoretical and applied economics under supervision of the graduate faculty.

66-521 Marketing **(4-0)4**

Prerequisite: 64-510 *Staff*

This course examines the process wherein the marketing strategies and plans of a competitive enterprise are formulated, implemented, and adjusted over time. Behavioral and quantitative aspects are covered, as well as analysis of the environmental forces affecting marketing decisions. The course is decision oriented and business cases are used extensively.

66-531 Finance **(4-0)4**

Prerequisite: 60-540 *Staff*

A study of financial principles and organization of business enterprise with emphasis on financial analysis, management of working capital, management of sources and cost of capital, and capital budgeting. Business cases, problems, readings, and reports.

66-551 Management of Human Resources **(4-0)4**

Staff

This course examines the management of human resources in a wide variety of industrial settings. Case studies and readings are drawn from a cross-section of American industry and from firms of various sizes. The emphasis is behavioral and is concerned with recognizing, analyzing, and predicting certain internal and external forces affecting business operations. Communications, decision-making, leadership, discipline, and company hiring practices are covered.

66-560 Business and Society **(3-0)3**

Staff

This course deals with the manager's role in understanding and determining the firm's relations with government and society. Topics relating to government include the tax and regulatory pro-

visions of local, state, and federal agencies including such matters as anti-trust, mergers, and licensing. Topics relating to society include the social cost aspects of business, civil rights, business ethics and problems in ecology.

66-571 Operations Research **(4-0)4**
Prerequisite: 64-511 *Staff*
This course covers classical optimization, programming techniques, Markov chains and queuing theory, and simulation exercises.

66-572 Operations Management **(4-0)4**
Prerequisite: 5. 64-511, 66-540 *Staff*
This course utilizes both behavioral and quantitative approaches to decision-making in manufacturing operations. Case studies are used extensively.

66-580 Business Problems and Policies **(4-0)4**
Prerequisites: 66-521, 66-531, 66-551, 66-571 and 66-572 *Staff*
This course emphasizes strategic long-range planning and organization to illustrate the inter-relationship of the various functional areas of business. Case analysis is used extensively to bring out the practical aspects of the total management problem.

66-599 Graduate Seminar
Research in any of the functional areas of management under the supervision of the graduate faculty.

66-651 Selected Topics in Management Science **(3-0)6**
Staff
Advanced topics in the various fields of management science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary management science.

66-701 Graduate Research in Management Science **(3-0)**
Staff
An independent investigation of a problem by a student in conference with a faculty advisor and approved by the student's advisor. A clear and systematic written presentation of the results is required.

66-751 Advanced Topics in Management Science **(1-0)1**
Staff
Special projects by a student to expand his knowledge in specific areas. Content and hours must be approved by the student's advisor.

Master of Business Administration (M.B.A.) Program

In September of 1977 the College of Management Science of the University of Lowell will offer the first year core courses of a two year M.B.A. degree program. The second year advanced courses, as well as the first year core courses, will be offered in September of 1978.

Admission is open to students who hold the baccalaureate degree from an accredited college. The Graduate Management Admission Test (GMAT) is required. Applications or letters of intent to apply should be received before June 30.

Full-time students may complete the degree in two academic years. Courses will be offered in the late afternoon and early evening to enable part-time students to complete the program in four academic years.

The curriculum consists of the following courses:

*First Year Core Courses** (To be offered beginning September, 1977 and thereafter)

FALL	SPRING
Financial and Managerial Accounting	Business Financial Analysis
Quantitative Analysis	Marketing
Microeconomic Theory	Operations Management
Human Resources Management	One course from the following:
	Control
	Macroeconomic Theory
	Operations Research

*Upon evaluation of transcript a limited number of core courses may be waived.

Second Year Advanced Courses (To be offered beginning September, 1978 and thereafter)

Students will take eight advanced courses to satisfy a concentration in Accounting; in Management with options in Finance, Marketing, Operations Management, or General Management; or in Public Finance-Urban Economics. Included in these courses will be a required course in Independent Study or Thesis and a required course in Business Policy or in Economic Analysis and Public Policy.

COLLEGE OF MUSIC

Members of the Graduate Faculty

Edward F. Gilday, *Dean Emeritus & Professor of Music;* B.S. Mus., A.M., New York University; D. Mus. A., Boston University; D. Litt. (Hon.) Emerson College; D.L.H. (Hon.) Boston College.

Thomas G. Elliot, *Acting Dean & Associate Professor, Music;* B.M.Ed., M.M., Boston University.

Artin Arslanian, *Professor, Music;* B.M., A.M., Ph.D., Boston University.

Donald Bravo, *Associate Professor, Music;* B.M., New England Conservatory of Music; M.M., Boston University.

Jacqueline Charette, *Associate Professor, Music;* B.M., Rivier College; M.M., Ed.D., Boston University.

Paul Earls, *Adjunct Professor, Music;* B.M., M.M., Ph.D., University of Rochester.

Paul Gayzagian, *Associate Professor, Music & Music Education;* B.M., M.M., Ed.D., Boston University.

Antone Holevas, *Associate Professor, Music; Chairman, Dept. of Performance;* B.M., Butler University; M.M., Boston University.

John Ogasapian, *Associate Professor, Music; Chairman, Dept. of Academic Studies;* B.M., M.M., Ph.D., Boston University.

Natalo Paella, *Assistant Professor, Music;* B.M., Louisiana State University; M.M., New England Conservatory of Music.

William Pordon, *Associate Professor, Music & Music Education;* B.M., M.M., Chicago Conservatory College.

Willis Traphagan, *Associate Professor, Music;* B.M., Ithaca College; M.M., Boston University.

Robert A. White, *Assistant Professor, Music;* B.M., New England Conservatory of Music; A.M., Harvard University.

Adjunct Applied Faculty

Eunice Alberts, *Voice;* New England Conservatory.

Ruth Allen, *Piano;* B.S., Ohio State University; M.M., Eastman School of Music.

Neil Anderson, *Lute and Guitar;* B.M., Hartt College.

Everett Beale, *Percussion;* New England Conservatory.

Norman Curtis, *Voice;* Curtis Institute.

Ruth Davidson, *Piano;* New England Conservatory.

Ira Deutsch, *Oboe;* B.M., M.M., New England Conservatory.

Thomas Ferrante, *Saxophone;* B.M., New England Conservatory; M.M., Boston University.

Thomas Foulds, *Trombone.*

Anthony Fulginiti, *Clarinet;* B.M., New England Conservatory.

Francis Gallagher, *Double Bass.*

Frank Gaviani, *Accordian;* B.M., Boston University.

Elsa Gerling, *Voice;* New England Conservatory.

Priscilla Hallberg, *Violin;* B.M., University of Iowa; M.M., Boston University.

Hal Janks, *Trombone.*

Alexandra Jaskolski, *Piano;* B.M., M.M., New England Conservatory.

Virginia Leguia, *Flute;* B.M., M.S., Juilliard School of Music.

Inge Lindblad, *Piano;* Diploma, Vienna Academy of Art; Diploma, Vienna Conservatory of Music; Senior Diploma, Longy School of Music.

Barbara McCloskey, *Voice;* A.B., Vassar College.

Deborah Moriarty, *Piano;* B.M., M.M., New England Conservatory.

Gary Ofenloch, *Tuba;* B.M., New England Conservatory.

Jeanne Paella, *French Horn;* B.M.E., Louisiana State University

Joseph Pietropaolo, *Viola;* Boston Symphony Orchestra.

Maryan Pietropaolo, *Cello;* B.M., New England Conservatory.

Isabelle Plaster, *Bassoon;* B.M., University of Louisville.

Myron Press, *Piano;* B.M., M.M., New England Conservatory.

Jay Rizetto, *Trumpet;* B.M., Lowell State College.

John B. Skelton, *Organ;* B.M., M.M., New England Conservatory.

Marsha Vleck, *Voice;* B.M., Oberlin College; M.M., Artist Diploma, New England Conservatory.

William Wrzesien, *Clarinet;* B.M.E., M.M., New England Conservatory.

George Zilzer, *Piano;* B.A., Harvard University; M.A., Bennington College; M.F.A., Brandeis University.

The College of Music offers the following degree programs:
MASTER OF MUSIC with a major in MUSIC EDUCATION
MASTER OF MUSIC with a major in PERFORMANCE
MASTER OF MUSIC with a major in MUSICOLOGY
MASTER OF MUSIC with a major in MUSIC THEORY-COMPOSITION

Admission to Degree Candidacy or Matriculation

In addition to the general admission policies listed on page 16, applicants for the M.M. degree with a concentration in Music Education must fulfill the following requirements:

1. Bachelor's degree or the equivalent with a major in music.
2. Teacher certification in Music
3. Successful audition in an area of applied music
4. A minimum of one year's music teaching experience before the degree can be conferred.
5. An official copy of the score earned on the Miller Analogies Test.

Master of Music Degree Program with a Major in Music Education

Required Courses

45-595 Aesthetics	3
01-621 Research Design	3
72-513,514 Applied Music	4
72-510,520 Ensemble	2
74-635 Research and Bibliography in Music	3
A course in Music History	3
A course in Music Theory	3
Two courses in Music Education	6

For those involved or interested in administration and supervision:

73-580 Administration and Supervision of Music Education	3

Students may choose between a program of 36 credit hours of courses approved by their adviser, or one of 30 hours with a thesis or lecture-recital. There may be a directed study on an individual basis taken in conjunction with the latter option. The thesis topic and outline, or the lecture-recital program must be accepted by the adviser and dean no later than one semester before the completion of requirements for the master's degree.

Students will fill out the balance of their programs with courses in the Humanities, Education, or Music, with the assistance and approval of their adviser.

In addition to the general admission policies listed on page 16, applicants for the M.M. degree with a concentration in PERFORMANCE, MUSICOLOGY, or MUSIC THEORY-COMPOSITION must fulfill the following requirements:

1. Bachelor's degree or the equivalent with a major in music
2. Successful audition in an area of applied music.
3. Satisfactory score on the Advanced Test on Music in the GRE's (not required for PERFORMANCE majors)

Master of Music Degree Program with Concentration in Musicology

45-595 Aesthetics	3
72-510,520 Ensemble	2
72-513,514 Applied Music	4
74 Musicology Courses (4)	12
71 A course in Music Theory	3
Thesis	6
Elective	3
74-635 Research and Bibliography in Music	3
	36

Master of Music Degree Program with Concentration in Performance

45-595 Aesthetics	3
72-610,620 Ensemble	4
72-515,516,615,616 Applied Music	8
74 A course in Music History	3
71 A course in Music Theory	3
Recital	6
Elective	6
74-635 Research and Bibliography in Music	3
	36

Master of Music Degree Program with Concentration in Music Theory — Composition

45-595 Aesthetics	3
72-510,520 Ensemble	2
72-513,514 Applied Music	4
71 Courses in Music Theory — Composition (4)	12
74 A course in Music History	3
Composition or Thesis	6
Elective	3
74-635 Research and Bibliography in Music	3
	36

Courses of Study

Applied Music

72-513,514 Applied Music I **(0,.5)2**
Staff

72-515,516,615,616 Applied Music II **(0,1)4**
Staff

72-510,520 Ensemble **(0,2)1**
Staff

72-610,620 Ensemble II **(0,4)2**
Staff

(Graduate students may fulfill the ensemble participation requirement through membership in such performing organizations as the Chamber Orchestra, Symphonic Winds, and the Concert Choir or by regular participation in smaller more specialized chamber ensembles.)

72-670 Workshop in Choral Music **(3-0)3**
Staff

In this course students will be exposed to advanced choral conducting techniques including score preparation, stylistic awareness, and tone quality. Choral literature from many periods including the 20th century will be studied, some for performance.

72-675 Advanced Vocal and Choral Techniques **(3-0)3**
Staff

This course will be an exhaustive investigation of the numerous factors involved in producing good choral work. Tone quality, balance, intonation, rehearsal techniques, programming, literature, are only a few of the areas to be analyzed and developed. Members of the class will be expected to contribute from their own choral experiences to the study.

72-676 The Conducting of Major Choral Literature **(3-0)3**
Staff

In this course the special problems of the performance of major choral works will be analyzed in detail, with reference to different interpretative styles. Students will be expected to present an analysis of at least one example of this form.

72-677 The Training of Children's Choruses **(3-0)3**
Staff

This course is designed to help music teachers develop good children's choruses by the demonstration of techniques of voice testing, development of good tone production, of effective rehearsal techniques, or ways of working well with children in music, of selection of appropriate literature, of teaching music reading during the rehearsal, of fostering appreciation of beautiful music.

72-740 Advanced Conducting I **(3-0)3**
Staff

In this course students will study techniques in conducting advanced literature and will demonstrate their proficiency by rehearsing choral and instrumental groups.

72-741 Advanced Conducting II **(3-0)3**
Staff

This course is an extension of 740.

72-291 Directed Study in Vocal Music **(3-0)3**
Staff

72-793 Directed Study in the Musical Theatre **(3-0)3**
Staff

Musicology

74-533 Chamber Music **(3-0)3**
Staff

A critical analysis of works for smaller instrumental ensembles from Haydn to Bartok.

74-538 History of Choral Music **(3-0)3**
Staff

A study of the choral repertoire from the Middle ages to the present, with detailed study of representative examples, and emphasis on trends on development, performance practice, and practical applicability.

74-555 Opera and Music Drama **(3-0)3**
Staff

This course traces the development of Opera from Monteverdi to the present.

74-630 The Development of Instrumental Forms **(3-0)3**
Staff

An intensive study of significant solo and orchestral works from Haydn to the present to show both the changes and underlying continuity of instrumental forms.

74-632 The Development of Vocal Forms **(3-0)3**
Staff

An analytical study of the art-song and larger choral works.

74-635 Research and Bibliography in Music **(3-0)3**
Staff

Students will compile personal music bibliographies, using the College library and outside collections. Proper form and style in research papers will be studied and practiced. Research techniques explained, e.g. procurement of microfilms of other library holdings, domestic and foreign, interlibrary loan, etc. Mock-thesis topics will be given, and proper procedures of research, musical concordance of several editions and primary sources, planning out papers, understanding of scholarly procedures, etc. will be practiced. (Fall, Spring)

74-637 Historical Development of Musical Form **(3-0)3**
Staff

A study of the forms of music from the twelfth century to the present, with an emphasis on the musical elements controlling the structures of various forms from the classical period (c. 1720) forward.

74-638 Historical Development of Musical Form II **(3-0)3**
Staff

This course is an extension of 74-637.

74-648 Johann Sebastian Bach **(3-0)3**
Staff

This course will concentrate on an examination of the major works of Bach from a chronological point of view. Major emphasis will be placed on how these compositions proclaim Bach as one of the greatest composers of all time.

74-650 Collegium Musicum **(3-0)3**
Staff

In this course students will investigate original sources of manuscripts of various periods, transcribe the music into modern notation, and participate in the performance of characteristic examples. Students may take this course for ½ credit as an Ensemble, in which case they would register for 72-510 or 511, or for 3 credits as a course in musicological research.

74-796 Directed Study in Musicology **(3-0)3**
Staff

Music Theory — Composition

71-520 Sixteenth Century Counterpoint **(3-0)3**
Staff

An intensive study of the music of the sixteenth century with special attention upon the basic principles of contrapuntal writing as they are exhibited in the works of such composers as Palestrina, Vittoria, and Byrd.

71-522 Structural Analysis **(3-0)3**
Staff

A study of the representative forms of music from the sixteenth century to the present with particular attention to free forms and the treatment of structure by twentieth century composers.

71-525 Electronic Music **(3-0)3**
Staff

The course will be in two parts, with time divided about equally between (1) a survey of the work of the leading figures in the development of electronic music, and (2) a workshop in the techniques of electronic sound synthesis and modification, and tape manipulation. Students will compose and perform their own electronic compositions.

71-583 Jazz Arranging I **(3-0)3**
Staff

An exploration of techniques in writing for various combinations of instrumental ensembles in the jazz idiom. Experience in playing or arranging for such groups is required for admission to this course. (By permission of dean only.)

71-584 Jazz Arranging II **(3-0)3**
Staff

A continuation of 71-583 Jazz Arranging I.

71-621 Fugue

A study of the technical detail of the fugue and of the influence of sixteenth century counterpoint upon the harmony of the eighteenth century. The interrelation of these two bases of music is illustrated by the fugues of J. S. Bach.

71-623 Composing and Arranging for Vocal and/or Instrumental Groups **(3-0)3**
Staff

A practical course in music with special attention given to writing for

groups for which there is little or no published music, such as choral and instrumental combinations on the junior high school level.

71-624 Twentieth Century Techniques in Composition (3-0)3
Staff

A contrapuntal and harmonic analysis of representative music of the twentieth century with practice in writing in the contemporary idioms and styles. (Fall)

71-626 The Analysis of Contemporary Music (3-0)3
Staff

A survey of recent musical works which lie clearly beyond the reach of traditional analytic techniques. "Chance," indeterminate, totally-serialized, stochastic and other mathematically-derived forms of music, etc., will be studied, with emphasis on developing new theoretical concepts appropriate to this music. Among the composers whose works will be studied are: Stockhausen, Cage, Boulez, Xenakis, Feldman, Brown, Tudor, Wolff, Hiller, Varese.

71-680 Advanced Instrumentation (3-0)3
Staff

In this course students will compose or arrange music for one or more of the instrumental ensembles of the University.

71-681 Advanced Orchestration (3-0)3
Staff

This course delves deeply into the attainment of balance among the several choirs of instrumental families. It also investigates the special demands of unusual instrumental combinations, both small and large. Students will be expected to write at least one example illustrating each of these approaches to orchestral writing.

71-790 Directed Study in Instrumental Music (3-0)3
Staff

71-791 Directed Study in Orchestration (3-0)3
Staff

71-794 Directed Study in Music Theory (3-0)3
Staff

71-795 Directed Study in Composition (3-0)3
Staff

Music Education

73-550 Developing Philosophies of Music Education (3-0)3

Staff

An examination and evaluation of current trends and directions in music education within the contexts of philosophical bases, historical references, aesthetic principles, and individual attitudes and opinion. Attention is also given to the problems of correlating philosophies of music and education and of developing a personal philosophy of music education to interpret both existing emerging programs.

73-553 Music and the Atypical Child (3-0)3

Staff

A challenging, stimulating rewarding opportunity for teachers. Music for children with special needs. Groupings, controls, activities, materials, techniques, evaluation, including ear-training (for teachers), instruments, reading, art, dance, perceptual and motor skills, physically handicapped and brain damaged.

73-555 Individualized Instruction in Music (3-0)3

Staff

In this course a critical analysis of the component tasks of the teaching-learning processes will be made with an emphasis upon the development of learning packages and teaching strategies for individualized instruction in music. Students will determine the area and level of these packages, ranging from vocal and instrumental music to content subject matter on the elementary, secondary, or higher levels. Special emphasis will be given the *compositional approach*, using the language laboratory facilities as a base of operations.

73-557 Workshop in Teaching Elementary Music (3-0)3

Staff

An activity approach to explore some current trends in elementary music — Orff, Kodaly, compositional approach, creative movement, program tape technique, as well as more traditional techniques. There will be a great deal of sharing of ideas, resources and materials.

73-560 Music and the Child (3-0)3

Staff

This course explores all phases of music as it can affect the child; much individualized attention is given to those with some learning disability in voice production, body movement, physical coordination, etc.

73-564 Affective Learning Through Music **(3-0)3**
Staff

Students will be involved in both the philosophical and practical realms of the affective domain so as to understand the importance of its integration in the music education curriculum. Specific activities in music and interpersonal relationships will be demonstrated, studied and practiced in a laboratory setting so that the student will be able to apply this knowledge and skill to his own educational and social milieu.

73-610 Workshop in the Teaching of Strings I **(3-0)3**
Staff

In this course students will learn techniques of teaching beginners and others how to play the string instruments and implement these methods under supervision. Some time will be spent on individual progress in one or more string instruments.

73-611 Workshop in the Teaching Strings II **(3-0)3**
Staff

An extension of 73-610.

73-612 Workshop in Teaching Winds and Percussion I **(3-0)3**
Staff

This course will be conducted in the same manner as 73-610, except that the instruments in question are all the winds and percussion.

73-613 Workshop in Teaching Winds and Percussion II **(3-0)3**
Staff

This course is an extension of 73-612.

73-658 Innovative Approaches to Music Teaching — Elementary Level **(3-0)3**
Staff

Teaching strategies for conceptual development to all levels. Exploration of related arts approach for enriching and integrating curriculum in today's schools. The music program as a catalyst to non-musical learning, designed to assist in development of basic skills (sensory-motor, perceptual-motor, language development and conceptual skills).

73-659 Innovative Approaches to Music Teaching — Secondary Level **(3-0)3**
Staff

This course corresponds to 73-658 on the Secondary level.

73-661 Developing New Curriculum Materials in Music (3-0)3
Staff
In this course students create curriculum materials in music based on the ideas of the children in the classroom and by inventing musical extensions of curriculum materials in other fields.

73-665 Teaching Music Through the Humanities (3-0)3
Staff
Techniques, materials, and equipment used in integrating history and literature with music and art with primary consideration given to the attitudes and psychological characteristics of secondary school students. (Spring)

73-666 Techniques of Group and Individual Vocal Training (3-0)3
Staff
A study of effective methods of class and individual vocal instruction, including an in-depth study of techniques for producing good singing and an examination of suitable literature and materials for various instructional situations.

73-667 Techniques of Group and Individual Instrumental Training (3-0)3
Staff
A study of effective methods of class and individual instrumental instruction, including guest lecturers in specialized areas, and examination of suitable literature and materials for various instructional situations.

73-669 Pedagogy of Music Theory I (3-0)3
Staff
This course will explore different approaches to the presentation of music theory in an effort to discover the best means of communicating this intangible subject to secondary school students.

73-670 Pedagogy of Music Theory II (3-0)3
Staff
This course extends the content covered in 73-669 — Pedagogy of Music Theory I — into the common practice of 19th century music, covering secondary dominants, 7th chords, chromatic harmony, remote modulation, and a look into some of the practices of the 20th century. Emphasis will remain on the exploration of the best approaches to the communication of this intangible subject matter to secondary school students. It is not necessary to have taken 73-669 as a prerequisite to this course.

73-680 Administration and Supervision of Music Education **(3-0)3**
Staff

An investigation of contemporary concepts of supervision and administration based upon reading, individual research, and group dynamics. Specific concerns will be administrative leadership, philosophy of administration and supervision, supervisory techniques, curriculum development, school budget, administrative responsibilities to professional personnel, administrative relationships with the community, and evaluation of supervisory and administrative activities.

73-790 Directed Study in Music Education **(3-0)3**
Staff

73-791 Directed Study in Teaching General Music **(3-0)3**
Staff

73-792 Directed Study in Teaching Elementary Music **(3-0)3**
Staff

73-793 Directed Study in Teaching Secondary Music **(3-0)3**
Staff

73-794 Directed Study in Teaching Instrumental Music **(3-0)3**
Staff

73-795 Directed Study in Teaching Vocal Music **(3-0)3**
Staff

73-796 Directed Study in Administration and Supervision of Music Education **(3-0)3**
Staff

73-797 Directed Study — Research in Music Education **(3-0)3**
Staff

Fine Arts

45-595 Aesthetics **(3-0)3**
Staff

In the first place, the course will examine the views of major philosophers on the beautiful and the nature of artistic creativity. Among others Plato, Aristotle, Augustine, Hegel, Nietzsche and Dewey will be considered. In the second place, an attempt will be made to correlate the views of these thinkers with the works of poets, artists and composers and the statements the latter have made about their work.

COLLEGE OF PURE AND APPLIED SCIENCE

John I. Bruce, B.S., Ph.D., Dean

BIOLOGICAL SCIENCES

Members of the Graduate Faculty

Robert M. Coleman, *Professor of Biological Sciences and Chairman of Department;* B.S., Bates College; M.S., University of New Hampshire; Ph.D., University of Notre Dame.

John I. Bruce, *Professor of Biological Sciences and Dean of College of Pure and Applied Science;* B.S., Morgan State College; Ph.D., Howard University.

Ilze Brunovskis Skare, *Assistant Professor of Biological Sciences;* B.A., University of Connecticut; Ph.D., Duke University.

Robert D. Lynch, *Assistant Professor of Biological Sciences;* A.B., Northeastern University; M.S., D. Sc., Harvard School of Public Health.

Timothy Macdonald, *Associate Professor of Biological Sciences;* B.A., Ph.D., University of Hawaii.

John C. Mallett, *Assistant Professor of Biological Sciences;* B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.

Nicholas J. Rencricca, *Associate Professor of Biological Sciences;* B.S., St. Francis College; M.S., St. John's University; Ph.D., Boston College.

Ezequiel R. Rivera, *Assistant Professor of Biological Sciences;* B.S., Sul Ross State College; M.S., Purdue University; Ph.D., University of Texas (Austin).

Master of Science Degree Program

The Department of Biological Sciences offers a Master of Science Program in Applied Biology. Students in the program will be encouraged to explore interdisciplinary approaches to the solution of problems related to the environment, as well as to those problems presently under investigation in applied and basic biomedical sciences. The student will have the option of selecting either an in-depth thesis program or an in-breadth course work program. In each instance, the curriculum is planned by the student with the advice and counsel of his advisor and a prescription committee. The advisor will advise him on his program of study and help him to become acquainted with research opportunities in the department, and assist him in selecting a thesis or project supervisor.

Entrance Requirements and Examinations

Admission requirements to the graduate program in biological sciences are the same as those prescribed by the Graduate School. The Department of Biological Sciences expects applicants to the

graduate program to have adequate preparation in biology, chemistry, mathematics and physics. A qualifying examination is not required by the Department. However, in the first semester of residence, all students are required to have an informal interview with the majority of the faculty present. Based on this interview, the faculty may require that deficiencies be made up by enrollment in appropriate courses. Students on provisional status will be required to have an interview before admission to the graduate program.

All students must maintain their academic performance in accordance with the requirements of the Graduate School. Not more than six credits of C will be allowed for the master's degree.

At the completion of the thesis or the master's project, the student is expected to present an oral defense of his work. This examination is open to the Department and the University.

Degree Requirements

1. Thesis Option — A minimum of 33 semester hours is required, and 9 semester hours of this total shall be taken as thesis credit. There is no formal language requirement. Each student's program is formulated on the basis of his possible research interests, background and professional goals in consultation with his advisor and Thesis Committee. In general the Committee will consist of the thesis advisor and at least two additional members, one of whom must be chosen from the Department of Biological Sciences.

2. Project Option — A minimum of 33 semester hours is required and 3 semester hours of this total shall be taken as project credit. There is no formal language requirement. Each student's program is formulated on the basis of his interests, background and professional goals in consultation with his advisor and the department chairman.

Research Programs

Members of this department are engaged in research programs in the following areas in which opportunities for advanced degree thesis or project research are offered:

Chemotherapy, epidemiology and physiology of parasitic diseases

Bacteriophage biochemistry and control of gene expression

Microbial genetics and physiology

Immunobiology of host-parasite relationships

Metabolic regulation, nutritional biochemistry and cell biology

Biochemical and developmental genetics in plants

Ecology, aquatic biology and ecological physiology

Erythropoietic control mechanisms in adult and newborn animals, kinetics of stem cell proliferation and differentiation

Biological ultrastructure, cytology, X-ray diffraction, plant anatomy, physiology and development, electron microscopy

Research Facilities

The department is housed in a new science building containing modern teaching and research facilities, office research modules, and service areas such as animal quarters, rooms for instrumentation, preparation and temperature control, as well as X-ray, electron microscope, greenhouse and growth chamber facilities.

Elective Course Listings

81-442G	Cytology	(3-0)3
81-444G	Cytology Laboratory	(0-3)1
81-456G	Endocrinology	(3-0)3
81-462G	Radiation Biology	(3-0)3
81-472G	Virology	(3-0)3
81-474G	Virology Laboratory	(0-3)1
81-506	Physiological Ecology	(3-0)3
81-508	Physiological Ecology Laboratory	(0-3)1
81-510	Limnology	(3-0)3
81-512	Limnology Laboratory	(0-3)1
81-515	Immunobiology	(3-0)3
81-517	Immunobiology Laboratory	(0-3)1
81-518	Immunoparasitology	(3-0)3
81-520	Immunoparasitology Laboratory	(0-3)1
81-522	Erythropoiesis	(3-0)3
81-524	Erythropoiesis Laboratory	(0-6)2
81-531	Current Concepts in Biochemistry	(3-0)3
81-533	Current Concepts in Biochemistry Laboratory	(0-3)1
81-541	Topics in Cell Biology	(3-0)3
81-552	Microbial Genetics	(3-0)3
81-554	Microbial Genetics Laboratory	(0-3)1
81-561	Electron Microscopy Theory	(3-0)3
81-562	Electron Microscopy Laboratory	(0-9)3
81-565	Selected Topics in Nutritional Biochemistry	(3-0)3
81-586	Cellular Immunology	(3-0)3
81-588	Cellular Immunology Laboratory	(0-3)1
81-592	Biochemical Genetics	(3-0)3
81-594	Biochemical Genetics Laboratory	(0-3)1
81-601-602	Graduate Seminar in Biology	(1-0) (1-0)2
81-651-652	Selected Topics in Biology	(3-0) (3-0)6
81-701-702	Graduate Research in Biology	(0-9) (0-9)6
81-751-752	Problems in Biology	(0-3) (0-3)2

Courses of Study

81-442 Cytology **(3-0)3**
Rivera
Deals with the cytoplasm incorporating the structure of cell membranes and the organelles they define; specialized organelles dealing with energy capture and transduction; some aspects of histochemical and biochemical studies on cytoplasmic organelles at the electron microscopic level. An introduction into cytogenetics and nuclear cytology; a brief discussion of prokaryotic cells.

81-444 Cytology Laboratory **(0-3)1**
Rivera
Introduction to the optical microscope as an analytical tool. Individual laboratories designed to acquaint the student with the analysis of biological ultrastructure at the optical and electron-microscopic level.

81-456G Endocrinology **(3-0)3**
Prerequisite: 81-252 or equivalent *Rencricca*
Structure and physiology of the endocrine glands. Emphasis will be given to the synthesis, transport, and mechanism of hormone action with regard to regulation of intermediary metabolism and maintenance of a homeostatic microenvironment. Endocrine imbalance, resulting in disease, will also be discussed.

81-462G Radiation Biology **(3-0)3**
Prerequisite: 81-252, 98-441 or equivalent *Rencricca*
A study of the interactions of radiations with living systems. The effects of ionizing radiation at the molecular, cellular and organismic levels. The acute and latent effects in whole animals and the modification of radiation exposure by physical, chemical and biological factors.

81-472G Virology **(3-0)3**
Prerequisite: 81-306, 81-371 *Brunovskis*
A study of bacterial, animal, and plant viruses including morphology and structure, serology, biochemistry of the infected cell, viral diseases of man, and oncogenesis. Emphasis is on virus-host interactions viewed at the molecular and genetic level. Concurrent registration in 81-474 is required for BI majors.

81-474 Virology Laboratory **(0-2)1**
Brunovskis
A series of laboratory exercises covering basic techniques in bacterial

and animal virology including virus propagation and titration, tissue culture, mutagenesis, and biochemical and biophysical characterization of viruses.

81-506 Physiological Ecology **(3-0)3**
Prerequisites: 81-252, 81-331 or equivalent *Mallett*
A consideration of physiological evolutionary and environmental aspects of interactions between organism and environment with special emphasis on homeostatic adaptations to biotic and abiotic environmental fluctuations. Concurrent registration in 81-508 is required for BI majors.

81-508 Physiological Ecology Laboratory **(0-3)1**
Mallett
A series of laboratory investigations designed to illustrate basic homeostatic adaptations enabling organisms to maintain internal constancy in a variable environment.

81-510 Limnology **(3-0)3**
Prerequisite: 81-112 and either 81-331 or 81-315 *Mallett*
An introduction to freshwater as a biogeochemical environment considering the geology, chemistry and physics of inland waters as they affect the ability of the medium to sustain life. Particular attention is addressed to basin and channel morphometry, thermal, photic, hydrologic and solvent properties of the medium. Floral and faunal components of the system are considered from populational and community aspects, evolutionary development and specific adaptations to particular niches in standing and flowing waters.

81-512 Limnology Laboratory **(0-3)1**
Mallett
A series of laboratory exercises designed to emphasize the material covered in 81-510.

81-515 Immunobiology **(3-0)3**
Prerequisite: 81-201 or equivalent *Coleman*
A study dealing with the biology of the immune response with sections on antibody production, reaction with antigen, suppression, tolerance, protection and injury. Concurrent registration in 81-483 is required for BI majors.

81-517 Immunobiology Laboratory **(0-3)1**
Coleman
A series of basic laboratory exercises dealing with the preparation, isolation and characterization of antigens, antibodies and effector cells.

81-518 Immunoparasitology **(3-0)3**
Prerequisite: 81-515 or equivalent *Bruce, Coleman*
The principles of animal parasitism are considered. The immunological aspects of the host-parasite relationship are stressed.

81-520 Immunoparasitology Laboratory **(0-3)3**
Bruce, Coleman
A series of laboratory exercises designed to emphasize the material covered in 81-518.

81-522 Erythropoiesis **(3-0)3**
Prerequisite: 81-252 or equivalent *Rencricca*
Components and physiology of the erythropoietic system. Emphasis will be given to the proliferation and differentiation of hemopoietic stem cells with regard to the regulation and maintenance of homeostasis. Abnormalities and perturbations resulting in diseased conditions will be discussed.

81-524 Erthropoiesis Laboratory **(0-6)2**
Rencricca
A series of laboratory exercises and projects to demonstrate basic and advanced techniques in hematology and which emphasize the material covered in 81-522.

81-531 Current Concepts in Biochemistry **(3-0)3**
Prerequisite: 81-306 or equivalent *Lynch*
A study concerned primarily with current research on biochemical mechanisms for the regulation of cellular metabolism. Recent developments in those areas of biochemistry concerned with the structure and function of biological membranes will also be examined. Concurrent registration in BI 533 is required for BI majors.

81-533 Current Concepts in Biochemistry Laboratory **(0-3)1**
Lynch
A series of laboratory experiments designed to acquaint the student with modern techniques in biochemistry and to emphasize material covered in 81-531.

81-541 Topics in Cell Biology **(3-0)3**
Prerequisite: 81-306, 81-371, or equivalent *Lynch, Rivera*
The fundamental structure and function of the cell will be discussed in detail. Some of the topics to be discussed are: 1. The anatomy and biochemistry of cellular membranes, 2. Transport mechanisms, 3. Systems developed by various life forms for motility, 4. Properties of

excitable cells. Wherever possible, comparisons between the biology of normal and transformed cells will be made.

81-552 Microbial Genetics **(3-0)3**
Prerequisite: 81-306, 81-201, 81-472 *Brunovskis*
A study of the principles and specialized techniques of genetic manipulation developed in experimental molecular biology with bacteria and viruses. Includes mutagenesis, mutant isolation, strain construction, chromosome transfer mechanisms, and mapping techniques. Concurrent registration in 81-554 is required for biology majors.

81-554 Microbial Genetics Laboratory **(0-3)3**
Brunovskis
A series of laboratory experiments designed to illustrate the material covered in 81-552.

81-561 Electron Microscopy — Theory **(3-0)3**
Prerequisite: 81-306, 81-308, Permission of Instructor *Rivera*
An introduction to the theory of electron microscopes and electron optics. Preparation of biological specimens for electron microscopic viewing and photography. Analysis of data obtained with electron microscopic techniques. Applications in biology will be discussed.

81-562 Electron Microscopy — Laboratory **(0-9)3**
Prerequisite: 81-561, Permission of Instructor *Rivera*
Operation of Scanning and Transmission Electron Microscopes. Project required of all students. Use of ancillary optical equipment.

81-565 Selected Topics in Nutritional Biochemistry **(3-0)3**
Prerequisite: 81-252, 81-306, or equivalent *Lynch*
This course deals with problems in basic and applied nutrition. Emphasis will be placed on nutrition in higher mammals, especially man. Recent evidence concerning the relationship between nutritional factors and disease states such as atherosclerosis, obesity, cancer, the common cold, and aging will be considered. The methods used for establishing minimum dietary requirements will be critically examined in the light of what is known about mechanisms by which animals adapt to varying supplies of nutrients.

81-586 Cellular Immunology **(3-0)3**
Prerequisite: 81-515, 81-517, or equivalent *Coleman*
Categories, cells, mediators, signals, interactions and regulation of immunological reactions involving cell-mediated immunity.

81-588 Cellular Immunology Laboratory **(0-3)1**
Coleman
A project laboratory designed to illustrate aspects of material covered in 81-586.

81-592 Biochemical Genetics **(3-0)3**
Prerequisites: 81-306 and 81-371, or equivalent *Macdonald*
A study of the biochemical structure and function of the eucaryotic genome. Roughly one half of the course deals with the molecular organization of the genetic material and transcriptional control in the eucaryote. The rest of the course focuses on enzyme and other polymorphisms, quantitative and qualitative variations, the null phenotype and inborn errors of metabolism. Subject areas include an indepth examination of the structure of the histones and nonhistones and their interaction with DNA, DNA sequences, renaturation kinetics, structures of transcripts and mechanisms of transcription, and positive and negative regulatory mechanisms of genetic expression in the eucaryote. Concurrent registration in 81-594 is required for biology majors.

81-594 Biochemical Genetics Laboratory **(0-3)1**
Prerequisites: Concurrent registration in 81-592 *Macdonald*
A series of laboratory experiments and projects designed to emphasize the material covered in 81-592.

81-601 Graduate Seminar in Biology **(1-0)1**
Staff
Presentation of individual reports by students and the instructor on advanced topics, original research or journal articles.

81-651 Selected Topics in Biology **(3-0)1**
Prerequisite: Permission of Instructor *Staff*
Advanced topics in various fields of biology. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary biology.

81-701 Graduate Research in Biology **(0-9)3**
Staff
An independent investigation of a problem which has been approved as a suitable subject for a Master's thesis.

81-751 Problems in Biology **(0-3)1**
Staff
Special problems in applied biology assigned to the individual student.

CHEMISTRY

Members of the Graduate Faculty

Joseph C. Salamone, *Professor of Chemistry and Chairman of Department;* B.S., Hofstra University; Ph.D., Polytechnic Institute of Brooklyn.

William W. Bannister, *Associate Professor of Chemistry;* B.S., Ph.D., Purdue University.

Eugene F. Barry, *Assistant Professor of Chemistry;* B.S., Villanova University, Ph.D., University of Rhode Island.

Alexandre Blumstein, *Professor of Chemistry;* B.S., Sorbonne, France; Ph.D., University of Strasburg, France.

Rita Blumstein, *Assistant Professor of Chemistry;* B.S., Sorbonne, France; Ph.D., University of Delaware.

Stuart B. Clough, *Assistant Professor of Chemistry;* B.S., University of Massachusetts; M.Ch.E., University of Delaware; Ph.D., University of Massachusetts.

Martin Isaks, *Associate Professor of Chemistry;* B.S., Purdue University; M.S., Iowa State University; Ph.D., University of Cincinnati.

Stanley C. Israel, *Assistant Professor of Chemistry;* B.S., Parsons College; Ph.D., Lowell Technological Institute.

Albert D. Kowalak, *Associate Professor of Chemistry;* B.S., College of William and Mary; M.S., Ph.D., Virginia Polytechnic Institute.

Phil S. Lamprey, *Professor of Chemistry;* B.S., Lowell Technological Institute; Ph.D., University of New Hampshire.

Vasilis Lavrakis, *Professor of Chemistry;* B.S., University of Massachusetts; M.S., Tufts University.

Irving Lipschitz, *Assistant Professor of Chemistry;* B.A., M.S., New York University; Ph.D., Virginia Polytechnic Institute.

Robert Litman, *Assistant Professor of Chemistry;* B.S., Brooklyn College; Ph.D., City University of New York.

Robert J. Peirent, *Professor of Chemistry;* B.S., M.S., Lowell Technological Institute.

James B. Pierce, *Professor of Chemistry;* B.S., Thiel College, M.S., Ph.D., Case Institute of Technology.

Chong Wha Pyun, *Associate Professor of Chemistry;* B.S., M.S., Seoul National University, Korea; Ph.D., Brown University.

Harry Rubinstein, *Professor of Chemistry;* B.S., Brooklyn College; Ph.D., Purdue University.

Allen Scattergood, *Professor of Chemistry;* B.A., Columbia University; Ph.D., Princeton University.

Arthur C. Watterson, Jr., *Professor of Chemistry and Assistant Chairman of Department;* B.S., Geneva College; Ph.D., Brown University.

Master of Science Degree Program

This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

Diagnostic-Evaluation Examinations

During the week of registration, each entering student must present himself for written examinations in four fields; organic, physical, inorganic and analytical chemistry. The examinations are the ACS Graduate Level Placement Exams and the student is expected to score in the 50th percentile or better for a passing mark. If a student gets below this mark on any examinations, he must take a second examination in the same area in May to be considered for the Ph.D. program.

Students performing poorly, i.e., well below the 50th percentile, on three examinations or more are not allowed to register as graduate students, but must register as special students.

Subject Requirements

Of the 18 credit minimum, exclusive of research and seminar, required in listed subjects, a minimum of 15 credits must be taken in chemistry. The remaining course credits (three or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit is normally not allowed for 400 level subjects in chemistry except for those designated in the catalog or approved by a student's advisor. Each graduate program in chemistry must include advanced subjects in organic chemistry, inorganic chemistry and physical chemistry unless such requirements have previously been met. All Students must take 84-601, Chemistry Seminar, each year they are in residence.

Although the design of the student's program is the responsibility of the Advisory Committee, the following listing provides a suggested core of subjects:

Chemistry — First Semester Subjects

84-431G	Advanced Physical Chemistry	(3-0)3
84-515	Chemical Literature	(2-0)2
84-523	Organic Reaction Mechanisms and Structure	(3-0)3
84-543	Modern Inorganic Chemistry	(3-0)3
84-601	Chemistry Seminar	(1-0)1
84-701	Graduate Research in Chemistry	(0-9)3

Chemistry — Second Semester Subjects

84-432G	Advanced Physical Chemistry*	(3-0)3
84-514	Advanced Analytical Chemistry	(3-0)3
84-516	Advanced Laboratory Technique	(1-3)2
84-524	Organic Synthesis*	(3-0)3
84-544	Modern Inorganic Chemistry*	(3-0)3
84-602	Chemistry Seminar	(1-0)1
84-702	Graduate Research in Chemistry	(0-9)3

Language Requirements

There is no language requirement for the M.S. degree in Chemistry.

Thesis Examination

Each candidate for the Master of Science degree in Chemistry must present himself for an oral examination in the field of his thesis before an examining committee appointed by the Department Chairman from the graduate faculty in chemistry. This examining committee normally will include the student's advisory committee plus an additional member of the graduate faculty. The chairman for the examination shall be the research advisor. While only members of the examination committee and the Dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Department Chairman at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

Doctor of Philosophy Degree Program

The doctoral program in chemistry is designed to provide the student with a background in advanced course work and chemical laboratory techniques that will prepare him to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires from three to four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is de-

*Although the student must take both semesters of the advanced subject in the field of his major, he may substitute 3-6 credits of the other two advanced subjects listed with an approved elective either in his first or second year. Students wishing to go on for the Doctorate should plan to take both semesters in all three fields.

veloped through conference with his advisory committee or, pending its appointment, with his temporary advisor.

All students entering the doctoral program must take the complete set of evaluation examinations given during the week of registration as described in the section relating to the Master of Science program in Chemistry. Only those students who have taken these examinations previously as candidates for the Master of Science program will be excused.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. His first year is usually given to subjects in the major branches of chemistry in preparation for his area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration.

The second and final part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to begin research as early as possible in his program of study.

Language Requirements

Demonstrate satisfactory reading ability in one foreign language (Level one), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the student advisory committee and approved by the Department.

Course Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, are required with a minimum of 18 to be taken in chemistry. The remaining course credits (9 or more, with a student's advisory committee having the authority to add six additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student's advisory committee and must include advanced subjects in organic chemistry, physical chemistry and inorganic chemistry. Where it is necessary to carry less than the normal credit load of 12 per semester, the student must apply to the Chairman of the Department through the chairman of his advisory committee.

Written Area Examinations

Upon admission to the Ph.D. program the student must pass exams in his major area of specialization. The method of conducting these

area exams is decided by the staff in each field of specialization. Analytical, Physical and Inorganic majors take a one-day written comprehensive encompassing the entire field of the major. Normally, it is taken before the beginning of the third year of graduate study. In the event of failure, one repetition of the exam is permitted. Organic majors take a series of cumulative exams which are designed to test the student's ability to handle information. A student is given eight chances to pass four examinations with a mark of pass or fail given for each examination. Students must take the examinations consecutively beginning the September following admission to the program. Students entering with an M.S. degree may take area examinations if they pass more than two diagnostic evaluation examinations upon entering in September; one of those passed must be in their field of intended specialization.

Research Proposition

As part of the area examination(s) a Ph.D. Candidate must present an oral defense of an original research proposal. With the aid and advice of his advisory committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's advisory committee with other faculty members in attendance. It is taken after completion of area exams and must be completed by the end of the semester following passing of area exams.

Chemistry Seminar

During each year of residence the student is required to attend and to participate in CH 601-602, Chemistry Seminar, (1-0) (1-0)2.

Course Offerings and Distribution

As a basis for the candidacy examinations the following core courses are recommended for the first-year students in the doctoral program:

84-431-432G	Advanced Physical Chemistry	(3-0) (3-0)6
84-514	Advanced Analytical Chemistry	(3-0)3
84-515	Chemical Literature	(2-0)2
84-516	Advanced Laboratory Techniques	(1-3)2
84-523	Organic Reaction Mechanism and Structure	(3-0)3
84-524	Organic Synthesis	(3-0)3
84-543-544	Modern Inorganic Chemistry	(3-0) (3-0)3

If the results from the diagnostic examinations indicate adequate background in any of the above subjects, substitution by a more advanced subject in the 500 series is recommended.

Additional subjects in chemistry or in the field of the minor may

be taken in the first year if desired, provided the prerequisites are met.

In the second year, subjects supporting concentration in specific fields are available as follows:

Analytical Chemistry

84-481G-482G	Nuclear and Radiochemistry	(2-3)3 (2-3)3
84-519	Environmental Chemistry	(3-0)3
84-526	Theory and Applications of Chromatography	(3-0)3
84-568	Structural Analysis	(3-0)3

Organic Chemistry

84-521	Physical Organic Chemistry	(3-0)3
84-527	Stereochemistry	(3-0)3
84-561	Advanced Organic Synthesis	(3-0)3
84-563	Chemistry of Natural Products	(3-0)3
84-565	Heterocyclic Chemistry	(3-0)3
84-568	Structural Analysis	(3-0)3

Physical Chemistry

84-531	Statistical Thermodynamics	(3-0)3
84-534	Quantum Chemistry	(3-0)3
84-535-536	Advanced Topics in Physical Chemistry	(3-0) (3-0)6
84-540	Chemical Kinetics	(3-0)3

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1. Complete the first year's core of recommended subjects and have satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. Pass the diagnostic evaluation and area examinations.
3. Fulfill the language requirements.
4. Secure the approval of his advisory committee and the Department Head.

When these requirements have been fulfilled, the Department Head notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

84-431G-432G Advanced Physical Chemistry (3-0) (3-0)6

Prerequisite: Permission of Instructor *Pyun*

Extension of introductory physical chemistry. Open to seniors and first-year graduate students in chemistry and related fields. Emphasis is placed on quantum chemistry of atoms and molecules as well as on classical and statistical thermodynamics.

84-434G Colloid Science and its Environmental Applications **(3-0)3**

Prerequisite: Permission of Instructor *A. Blumstein*

An introduction to the fundamentals of colloid and interface science. Topics discussed include solid/gas, solid/liquid, and liquid/liquid interfaces: association colloids, emulsion suspension, aerosols, smog and foams. Additional topics include applications of colloid science to environmental problems, flocculation and stability, adsorption and ion exchange, ultrafiltration, reverse osmosis, and electro-kinetic phenomena.

84-481-482G Nuclear and Radiochemistry **(2-3) (2-3)6**

Prerequisite: Permission of Instructor *Lavrakas*

Fundamentals of radiochemistry, including radioactivity, atomic nuclei, nuclear reactions, reactors, and radiation detection and measurement, with emphasis on the use of radioactive materials in chemical applications. Designed primarily for majors in chemistry and allied fields.

84-502 Color Science **(2-3)3**

Prerequisite: Permission of Instructor *Peirent*

Theory and application of absorption spectrophotometry to the qualitative and quantitative analyses of chemical substances in both transparent and opaque media in the ultra-violet, visible, and new infrared ranges, including theories of color, vision, and subjective color evaluation.

84-513 Spectroscopy **(3-0)3**

Prerequisite: 84-431-432 or equivalent *Lipschitz*

A presentation of molecular spectra and molecular structure is presented to illustrate the empirical results and the theoretical background necessary to interpret the results.

84-514 Advanced Analytical Chemistry **(3-0)3**

Prerequisite: 84-431 or equivalent *Lipschitz*

Advanced analytical techniques based on physical-chemical principles are utilizing instrumental methods wherever applicable. The analytical use of complexes, radiant energy methods, electrochemistry, chromatography, polarography, analytical applications of radioisotopes, and physical methods of separation.

84-515 Chemical Literature **(2-0)2**

Prerequisite: Permission of Instructor *Rubinstein*

Use of the chemical library, journals, reference works and other

technical publications pertaining to chemical subjects. Exercises in finding, assembling and using such data.

84-516 Advanced Laboratory Techniques **(1-3)2**
Prerequisite: Permission of Instructor *Rubinstein*
A study of the theory and application of the more advanced techniques and equipment in the preparation and purification of organic compounds, including high efficiency fractionation, vacuum and molecular distillation, hydrogenation and reactions in inert atmosphere.

84-517 Glass Working **(1-0)1**
Prerequisite: Permission of Instructor *Rubinstein*
Fundamental techniques in the preparation and assembling of glass apparatus.

84-519 Environmental Chemistry **(3-0)3**
Prerequisite: 84-311 or equivalent *Litman*
A study of the reactions involving atmospheric and aquatic pollutants. Included are such topics as the oxides of nitrogen, carbon, and sulfur, particulate matters in air, and equilibria occuring in natural waters. Approved "wet" and instrumental methods of analysis of pollutants of current interest are also presented.

84-521 Physical Organic Chemistry **(3-0)3**
Prerequisite: 84-523-524 or equivalent *Isaks*
Modern and classical methodology in the study of organic reactions. Linear free energy relationships, tracer methods, orbital symmetry and other selected topics will be covered.

84-523 Organic Reaction Mechanisms and Structures **(3-0)3**
For graduate students only *Isaks*
Designed to provide insight into how reactions occur and how the reactions mechanism is studied. Emphasis is placed on bonding, substitution and elimination processes, stereochemistry, and conformational analysis.

84-524 Organic Synthesis **(3-0)3**
For graduate students only *Rubinstein*
Mechanism, scope and limitations of important selected types of reactions, and designs of synthetic sequences. Emphasis is placed on reduction, oxidation, halogenation, alkylation, and acrylation.

84-526 Theory and Applications of Chromatography (3-0)3
Prerequisite: Permission of Instructor *Barry*
A treatment of the theory underlying chromatographic separations and processes. Included are such topics as gas-liquid, gas-solid, thin-layer, column and gel permeation chromatography. Applications of the various chromatographic methods are discussed.

84-527 Stereochemistry (3-0) (3-0)6
Offered in alternate years *Staff*
The fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

84-531 Statistical Thermodynamics (3-0)3
Prerequisite: 84-432 or equivalent *Staff*
Fundamentals of equlibrium statistical mechanics, classical and quantum statistics. Molecular theories of gases, crystals, and liquids, with emphasis on chemical aspects. Electrolyte and nonelectrolyte solutions, polymer and polyelectrolyte systems, chemical equilibria and reaction rate processes. Also, introduction to nonequilibrium statistical theories.

84-534 Quantum Chemistry (3-0)3
Prerequisite: 84-431 or equivalent *Staff*
Principles and methods of quantum mechanics with special attention to chemical applications, such as electronic nature of atoms and molecules, vibrations and rotation of molecules, and interaction of radiation with matter.

84-535-536 Advanced Topics in Physical Chemistry (3-0) (3-0)6
Staff
Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

84-540 Chemical Kinetics (3-0)3
Prerequisite: 84-432 or equivalent *Kowalak*
The theoretical and empirical treatment of chemical kinetic data as well as the methods of obtaining these data. Determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanism, collision theory, and absolute rate theory.

84-543-544 Modern Inorganic Chemistry (3-0) (3-0)6
Prerequisite: Permission of Instructor *Kowalak*
Similar to 84-443-444 but designed specifically for graduate stu-

dents. Emphasis is placed on the theory of the chemical bond, bonding in complexes, coordination theory, spectroscopic methods, non-aqueous solvent systems.

84-561 Advanced Organic Synthesis **(3-0)3**
Prerequisite: 84-523-524 or equivalent *Watterson*
Offered 1974-75 and alternate years
The application of known organic reactions to the synthesis of chemical species in such fields as the terpenes, steroids, alkaloids, antibiotics and selected heterocyclic derivatives.

84-563 Chemistry of Natural Products **(3-0)3**
Prerequisite: 84-568, 84-311 or equivalent *Watterson*
An advanced subject covering the proof of structure of various types of natural products, approaches to the total synthesis of some and also the biosynthetic pathways.

84-565 Heterocyclic Chemistry **(3-0)3**
Prerequisite: Permission of Instructor *Watterson*
Offered 1975-76 and alternate years
Classification, nomenclature, structure, synthesis and utility of the more important classes of heterocyclic compounds.

84-568 Structural Analysis **(3-0)3**
Prerequisite: Permission of Instructor *Watterson*
Practical application of instrumental data in the determination of the structure of organic compounds. Includes mass spectroscopy, ultraviolet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy.

84-575 Chemical Analyses for Water Quality **(2-3)3**
Staff
The principles of chemical water analysis, with emphasis on sampling methods, selected analytical procedures, control techniques and interpretations. Lecture-discussion sessions, laboratory demonstrations, and guest speakers will also stress the validity of chemical criteria related to water pollution control, and compliance with water quality standards.

84-601 Chemistry Seminar **(1-0) (1-0)2**
Required of all graduate students *Staff*
Presentation of current topics by visiting scientists, staff and graduate students.

84-651 Selected Topics in Chemistry **(3-0) (3-0)6**

Prerequisite: Permission of Instructor *Staff*

Advanced topics in the various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

84-701 Graduate Research in Chemistry **(0-9) (0-9)6**

Staff

An independent investigation of a problem by the student in conference with a faculty advisor and approved by the Department Head. A clear and systematic written presentation of the results is required.

84-751 Advanced Projects in Chemistry **(0-3) (0-3)2**

Staff

Special projects laboratory undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by the Department Head.

MATHEMATICS

(Including Applied Mathematics)

Members of the Graduate Faculty

Alan W. Doerr, *Assistant Professor of Mathematics and Chairman of the Department;* B.S., Marist College; M.A., Hunter College.

Donald L. Ameen, *Assistant Professor of Mathematics;* B.S., Lowell Technological Institute; M.S., Cornell University.

Shimshon Berkovits, *Assistant Professor of Mathematics;* B.S., Massachusetts Institute of Technology; M.A., University of Chicago; Ph.D. Northeastern University.

Thomas M. Costello, *Assistant Professor of Mathematics;* B.S., Boston College; M.S., Ph.D., University of Maryland.

Alan Kaplan, *Assistant Professor of Mathematics;* B.S., University of Massachusetts; M.S., Ph.D., Syracuse University.

Joseph L. Neuringer, *Professor of Mathematics;* B.A., Brooklyn College; M.A., Columbia University; Ph.D., New York University.

Garfield C. Schmidt, *Associate Professor of Mathematics;* B.S., M.S., Kansas State University; Ph.D., University of New Hampshire.

Stanley Spiegel, *Assistant Professor of Mathematics;* B.S., New York University; A.M., Ph.D., Harvard University.

I. Jacob Weinberg, *Professor of Mathematics;* B.S., Yeshiva University; M.S., Ph.D., Massachusetts Institute of Technology.

Joyce W. Williams, *Instructor of Mathematics;* B.A., University of Minnesota; M.S., Ph.D., University of Illinois.

Associates of the Graduate Faculty

Stephen J. Bodor, *Professor of Mathematics;* B.S., Lowell Technological Institute; M.S., Lowell Technological Institute.

Pasquale Condo, *Assistant Professor of Mathematics;* B.S., Purdue University; M.S., Lowell Technological Institute.

Michael Grossman, *Assistant Professor of Mathematics;* B.S., Tufts University; M.A., Yale University.

Virginia S. Taylor, *Assistant Professor of Mathematics;* B.S., Syracuse University; M.A., Western Michigan University.

Master of Science Degree Program

The graduate program in mathematics is designed to provide training on the Master's level in pure and applied mathematics leading to academic and industrial careers.

Each student admitted to graduate study will be assigned a

faculty advisor by the Department Head to supervise the preparation and periodic revision of his plan of study.

An applicant for admission to graduate study is expected to have an adequate preparation in mathematics including a year of introductory real analysis and a semester of linear algebra. A student deficient in his preparation may be required to take undergraduate prerequisites which do not carry graduate credit.

Each student's program, formulated by him in consultation with his faculty advisor, must receive the approval of the Department Chairman. This program, constituting a minimum of thirty credit hours, will consist of a selection of courses from several areas of mathematics together with further specialization in one area. Graduate course offerings of other departments may be considered for inclusion in the program of study.

As part of his program each candidate must complete a thesis, normally consisting of six credit hours, or a project. The student must propose a thesis or a project with the approval of his advisor. Upon completion of his thesis or project the student must present a defense for approval by a committee of three faculty members assigned by the Department Chairman of which the thesis project advisor is chairman.

Courses of Study

92-421G-422G Abstract Algebra **(3-0) (3-0)6**
Doerr

Group theory, groups, cosets, normal subgroups, quotient groups, isomorphisms, homomorphisms, series of groups. Sylow theorems and homology groups. Ring and field theory. Ideals. Rings of polynomials. Algebraic extensions. Automorphisms of fields. Galois theory. Categories and functors.

92-431G-432G Topology **(3-0) (3-0)6**
Grossman

Topological spaces. Continuity. Compactness and connectedness. Product and quotient spaces. Metric spaces. The fundamental group. Topological groups.

92-442G Boundary Value Problems **(3-0)3**
Bodor

Fourier series in analysis. Orthogonal functions. Convergence tests. Fournier integral. Partial differential equations. Boundary value problems.

92-501-502 Real Analysis **(3-0) (3-0)6**

Kaplan

Real and complex number systems. Set theory. Bolzano-Weierstrass and Heine-Borel Theorems. Sequences and series. Continuity. Differentiation. Riemann integration. Sequences and series of functions. Functions of several variables.

92-503-504 Functional Analysis **(3-0) (3-0)6**

Neuringer

Vector spaces, metric spaces, operators in metric spaces, normed spaces. Hilbert spaces. Linear operators, linear functionals, adjoint and self-adjoint operators in Hilbert space. Approximate solutions of functional equations. Partially ordered normed spaced.

92-507 Real Variables Theory **(3-0)3**

Kaplan

Real valued functions. Continuity, semi-continuity, bounded variation, absolute continuity, differentiability, integrability. Lebesque measure and integration theory.

92-511-512 Complex Analysis **(3-0) (3-0)6**

Williams

Complex numbers, analytic functions. Cauchy integral theorem. Cauchy integral formula. Power series. Residues. Applications. Entire functions. Picard's theorems. Riemann mapping theorems. Analytic continuation. Riemann manifolds. Weirstrass monodromy, Wierstrass factor and Mittag-Leffler theorems.

92-521-522 Algebraic Structures **(3-0) (3-0)6**

Doerr

Properties of rings, groups and modules in the framework of categorical algebra. Divisibility theory in integral domains. Linear and multilinear algebra. Field extensions and Galois theory. Homology groups.

92-531 Algebraic Topology **(3-0)3**

Staff

The fundamental group, covering spaces and polyhedra. Singular homology, universal coefficient theorem. Homology and cohomology operation. Homotopy theory.

92-535 Higher Geometry **(3-0)3**

Staff

Algebraic Geometry, transformation groups and invariants, projec-

tive transformation, involutions, polarities, conics, non-euclidian geometrics.

92-537-538 Tensor Analysis **(3-0) (3-0)6**

Staff

Algebra of tensors in n-dimensional space. Calculus of covariant and contravariant absolute and relative tensors. Applications to differential geometry, dynamics, continuum mechanics and relativity.

92-543-544 Ordinary Differential Equations **(3-0) (3-0)6**

Neuringer

Existence theorems. Linear systems. Regular and irregular singular points. Boundary value problems including non-self adjoint case. Stability theory and perturbation theory. Periodic orbits. Limit cycles.

92-545-546 Partial Differential Equations **(3-0) (3-0)6**

Spiegel

First and second order equations. Transformation theory in plane and space. Applications. Classification and methods of solution. Properties of solutions of equations with initial and boundary conditions. Existence and uniqueness theorems.

92-547 Integral Equations **(3-0)3**

Neuringer

Exact, iterative and numerical techniques for the solution of linear Volterra and Fredholm integral equations, theorems for general operators, symmetric kernels, orthogonal system of functions, and the Hilbert-Schmidt theorem, relation of integral equations to differential equations, applications of the Rayleigh-Ritz, Galerkin, and variation-iteration techniques to the solutions of eigenvalue-eigenfunction problems occurring in mathematical physics and engineering.

92-551 Calculus of Variations **(3-0)3**

Weinberg

The first variational problem. Necessary conditions. Euler's equation. Several dependent and independent variables. Constraints and Lagrange multipliers. Applications to dynamics and elasticity. Hamilton equations. Sturm-Lionville problems. Direct methods. Rayleigh-Ritz method.

92-561 Approximation Theory **(3-0)3**

Weinberg

Approximation techniques for functions. Interpolation, rational approximation, orthogonal functions.

92-563-564 Advanced Numerical Analysis **(3-0) (3-0)6**

Spiegel

Solutions of algebraic equations. Interpolation, differentiation and integration. Least squares and orthogonal polynomials. Ill-conducting Linear equations. Eigenvalues. Ordinary and partial differential equations.

92-571-572 Optimization and Mathematical Programming **(3-0) (3-0)6**

Costello

Linear Programming, simplex methods, dual problem, transportation problem, assignment problem, sensitivity analysis, introductory integer programming and applications of each of the techniques. Second semester covers Integer Programming, network flows and analysis, classical nonlinear optimization, Lagrange Multipliers, Kuhn-Tucker conditions, nonlinear programming and some of the Calculus of Variations.

92-584 Analysis of Random Processes **(3-0)3**

Staff

Axiomatic definition of probability. Combined experiments. Bernoulli trials. Asymptotic Theorems. Bayes theorem. Discrete and continuous random variables. Functions of several random variables. Continuous probability density functions. Expected value, moments, characteristic functions, estimations. Sequences continuous random variables. Law of large numbers.

92-585 Stochastic Processes **(3-0)3**

Staff

Definition of stochastic processes. Expected values and generating functions. Convergence, continuity, differentiability and integration of random functions. Stationary processes and ergodic theorems. Theory of recurrent events. Markov chains and processes. Brownian motions.

92-587-588 Probability Theory and Stochastic Processes **(3-0) (3-0)6**

Costello

Develops probability theory from the Kolmogorov axioms. Analysis of discrete and continuous random variables. Joint density and joint distributions, changes of variables, expectations, variance and higher moments. Laws of large numbers and central limit theorem. Decision theory and Prediction theory. Sequences of random variables, stochastic processes; Bernoulli, Poisson and Normal Processes; Stationary and Independent Increments; Markov Processes, Queueing Theory; Estimation Theory.

92-651 Selected Topics in Mathematics **(3-0)3 (3-0)**

Staff

Advanced topics in various fields of mathematics. Content may vary from year to year.

92-701 Graduate Research in Mathematics **(3-0)3**

Staff

Mathematical research. Open only to students engaged in thesis research.

MATHEMATICS FOR TEACHERS

Members of the Graduate Faculty

Donald L. Ameen, *Assistant Professor of Mathematics and Program Director;* B.S., Lowell Technological Institute; M.S., Cornell University.

Shimshon Berkovits, *Assistant Professor of Mathematics;* B.S., Massachusetts Institute of Technology; M.S., University of Chicago; Ph.D., Northeastern University.

Thomas M. Costello, *Assistant Professor of Mathematics;* B.S., Boston College; M.S., Ph.D., University of Maryland.

Alan W. Doerr, *Assistant Professor of Mathematics and Program Coordinator;* B.S., Marist College; M.A., Hunter College.

Alan Kaplan, *Assistant Professor of Mathematics;* B.S., University of Massachusetts; M.S., Ph.D., Syracuse University.

Joseph L. Neuringer, *Professor of Mathematics;* B.A., Brooklyn College; M.A., Columbia University; Ph.D., New York University.

Garfield C. Schmidt, *Assistant Professor of Mathematics;* B.S., M.S., Kansas State University; Ph.D., University of New Hampshire.

Stanley Spiegel, *Assistant Professor of Mathematics;* B.S., New York University; A.M., Ph.D., Harvard University.

I. Jacob Weinberg, *Professor of Mathematics and Chairman of Department;* B.S., Yeshiva University, S.M., Ph.D., Massachusetts Institute of Technology.

Associates of the Graduate Faculty

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Michael Grossman, *Assistant Professor of Mathematics;* B.S., Tufts University; M.A., Yale University.

Virginia S. Taylor, *Assistant Professor of Mathematics;* B.S., Syracuse University; M.A., Western Michigan University.

Master of Mathematics Degree Program

The program for a Master's degree for teachers of mathematics follows the general policies of University of Lowell for graduate education. It is designed to provide a sound basis in the areas of Analysis, Algebra, Geometry, and Applied Mathematics, with more intensive study in any one or more of these four areas. Qualified students with backgrounds in the teaching of mathematics or any of the related sciences are eligible for admission to the program. Course offerings will be scheduled at times convenient for teachers (e.g. 6-9 P.M.).

An applicant for admission to graduate study is expected to meet the general requirements outlined in the University of Lowell Graduate Bulletin and to have adequate preparation in mathematics. However, mathematics teachers at either the elementary or secondary level are not required to take the Graduate Record Examination (GRE). As minimum prerequisites, candidates for this program should have completed two years of mathematics including one year of calculus. A student judged to be deficient in this area may be required to complete certain undergraduate courses prior to full acceptance into the program. There are no residence requirements. With regards to degree requirements, a minimum of thirty semester hours is required. A permanent departmental committee arranges each candidate's program on an individual basis in the light of his or her background and needs. Normally the degree program will consist of six credit hours in Analysis beyond 90-801, three in Algebra, three in Geometry, and three in Applied Mathematics, the remaining fifteen to be chosen from any one of these four areas. As many as six of the latter fifteen credits may be obtained through guided individual study of an approved topic.

Courses of Study

The course work for the program is similar in content to any graduate program in mathematics with the exception that each course is geared to the needs of the teacher.

I. Analysis

92-801 Analysis **(3-0)3**
Staff

Calculus from an advanced viewpoint. The course is designed to provide teachers with the background necessary to teach Advanced Placement Mathematics.

92-803 Real Analysis I **(3-0)3**
Staff

Equivalence and countability. Sets, sequences, and series of real numbers. Metric spaces. Limits and continuity.

92-804 Real Analysis II **(3-0)3**
Staff

Derivatives, The Riemann integral, and the Fundamental Theorem of Calculus. The Lebesque Integral and Lebesque's Dominated Convergence theorem. Further topics.

92-811 Complex Analysis I **(3-0)3**
Prerequisite: Permission of Instructor *Staff*
Complex numbers, point sets, and elementary functions; an introduction to analytic functions; classification of singularities; line integrals; Cauchy integral formula; power series and residues and poles.

92-812 Complex Analysis II **(3-0)3**
Prerequisite: 90-811 *Staff*
Conformal mapping, Schwartz-Christoffel transformation, applications and further topics in Theory of Functions.

92-851 Introduction to Topology **(3-0)3**
Prerequisite: Permission of Instructor *Staff*
Metric spaces; topological spaces, connectedness; compactness, elements of point-set topology and the Fundamental Group.

92-882 Advanced Topics in Analysis **(3-0)3**
Prerequisite: Permission of Instructor *Staff*

II. Algebra

92-821 Linear Algebra I **(3-0)3**
Staff
Mathematical induction; the properties of sets; Mappings and mathematical logic; vectors in Rn; vector spaces; matrices; linear mappings; the effect of a change of basis; the matrix associated with a linear map; application to geometry.

92-822 Linear Algebra II **(3-0)3**
Prerequisite: 92-821 *Staff*
Scalar products and orthogonality; matrices and bilinear maps; polynomials and matrices; triangulation of matrices and linear maps; the Spectral Theorem; matrix analysis; applications to differential equations.

92-831 Abstract Algebra I **(3-0)3**
Staff
Elementary Group Theory; groups; cosets; normal subgroups; quotient groups; isomorphisms; homomorphisms; series of groups and the Sylow-Theorems.

92-832 Abstract Algebra II **(3-0)3**
Prerequisite: 92-831 *Staff*
Elementary ring and field theory, quotient rings and ideals;

homomorphisms or rings of polynomials; algebraic extensions; automorphisms of fields; separable extensions; Galois theory.

92-883 Advanced Topics in Algebra **(3-0)3**
Prerequisite: Permission of Instructor *Staff*

III. Geometry

92-841 Geometries I **(3-0)3**
Staff

Euclid's and Hilberts axioms; non-Euclidean geometries, the space concept and an introduction to basic topological concepts.

92-843 Geometries II **(3-0)3**
Staff

A continuation of Geometries I; synthetic and analytic treatment of projective transformations, duality, conics poles, involution.

92-842 Differential Geometry **(3-0)3**
Staff

The Geometry of curves and surfaces; Serret-Fronet formulas; intrinsic equations of a curve; first and second fundamental forms of a surface.

92-851 Introduction to Topology **(3-0)3**
Prerequisite: Permission of Instructor *Staff*

Metric spaces; topological spaces, connectedness; compactness; elements of point-set topology and the Fundamental Group.

92-884 Advanced Topics in Geometry **(3-0)3**
Prerequisite: Permission of Instructor *Staff*

IV. Applied Mathematics

92-861 Topics in Applied Mathematics I **(3-0)3**
Staff

Series solutions of ordinary differential equations, special functions, Laplace transformation.

92-862 Topics in Applied Mathematics II **(3-0)3**
Staff

Fourier series and integrals, boundary value problems and orthogonal functions, partial differential equations in engineering problems, vector calculus.

92-865 Statistics (3-0)3
Staff

Methods of data reduction and graphic presentation; measures of central tendency and variability; study of probability distributions both discrete and continuous; estimation theory; introduction to hypothesis testing; sampling theory; regression and correlation; analysis of variance; education applications and non-parametric statistics.

92-871 Digital Computer Programming (3-0)3
Staff

An introduction to digital computer programming with concentration on the preparation of programs in the Fortran programming language. The Institute's Computer will be used for processing of practice problems.

92-872 Numerical Analysis (3-0)3
Prerequisite: 90-871 or Permission of Instructor *Staff*

Numerical methods for solving engineering problems including: finite and divided differences, collocation polynomials, interpolation, numerical integration and differentiation, solution of differential equations, systems of linear and nonlinear equations, root-finding techniques, and curve fitting. Computer applications are stressed throughout.

92-885 Advanced Topics in Applied Mathematics (3-0)3
Prerequisite: Permission of Instructor *Staff*

Seminar

92-880-881 Mathematics Seminar (3-0)3
Prerequisite: Permission of Instructor *Staff*

This course will concentrate on a critical discussion of the central problems involved in any one or more of the four areas of Analysis, Geometry, Algebra, or Applied Mathematics.

PHYSICS AND APPLIED PHYSICS

Members of the Graduate Faculty

Gunter H. R. Kegel, *Professor of Physics and Applied Physics and Chairman of Department;* B.Fis., F.N.Fis, Universidade do Brasil; Ph.D., Massachusetts Institute of Technology.

Leon E. Beghian, *Professor of Physics and Applied Physics and Provost;* B.A., D. Phil., University of Oxford.

Albert Altman, *Professor of Physics and Applied Physics;* B.S., Brooklyn College; M.S., Ph.D., University of Maryland.

Adolph Baker, *Professor of Physics and Applied Physics;* B.A., City College of New York; B.M.E., Polytechnic Institute of Brooklyn; M.S., in Ed., City College of New York; M.S., New York University; Ph.D., Brandeis University.

Barry K. Barnes, *Assistant Professor of Physics and Applied Physics;* B.A., M.A., Ph.D., Rice University.

C. Daniel Cole, *Professor of Physics and Applied Physics;* B.A., Ph.D., University of Buffalo.

Gus P. Couchell, *Associate Professor of Physics and Applied Physics;* B.S., M.S., North Carolina State University; Ph.D., Columbia University.

James J. Egan, *Associate Professor of Physics and Applied Physics;* B.A., Thomas More College; M.S., Ph.D., University of Kentucky.

Zoltan Fried, *Professor of Physics and Applied Physics;* B.S., Brooklyn College, Ph.D., Brandeis University.

Padmanabh Harihar, *Associate Professor of Physics and Applied Physics;* B.Sc., R. Ruia College; M.Sc., Wilson College, India; Ph.D., Columbia University.

Lloyd C. Kannenberg, *Associate Professor of Physics and Applied Physics;* B.S., Massachusetts Institute of Technology; M.S., University of Florida; Ph.D., Northeastern University.

Aram S. Karakashian, *Assistant Professor of Physics and Applied Physics;* B.A., M.A., Temple University; Ph.D., University of Maryland.

David Korff, *Professor of Physics and Applied Physics;* B.A., Harvard University; Ph.D., Brandeis University.

Suresh C. Mather, *Professor of Physics and Applied Physics and Director of the Computer Center;* B.Sc., University of Lucknow; Ph.D., University of Texas.

Arthur I. Miller, *Professor of Physics and Applied Physics;* B.S., The City College of New York; Ph.D., Massachusetts Institute of Technology.

Arthur Mittler, *Assistant Professor of Physics and Applied Physics;* B.A., Drew University; M.S., Ph.D., University of Kentucky.

M. Ali Omar, *Professor of Physics and Applied Physics;* B.S., Colorado School of Mines; M.S., Ph.D., University of Colorado.

David J. Pullen, *Professor of Physics and Applied Physics;* B.Sc., University of London, D. Phil., University of Oxford.

Paul J. Ring, *Assistant Professor of Physics and Applied Physics;* B.S., Boston College, M.S., Rensselaer Polytechnic Institute; Ph.D., Brown University.

Walter A. Schier, *Associate Professor of Physics and Applied Physics;* B.S., Saint Procopius College; Ph.D., Notre Dame.

Kunnat J. Sebastian, *Assistant Professor of Physics and Applied Physics;* B.S., Kerala State College; M.S., Kerala University; Ph.D., University of Maryland.

Eric Sheldon, *Professor of Physics and Applied Physics;* B.Sc. (Gen) and B.Sc. (Special Honors), D.Sc., D. Phil., University of London.

Richard W. Stimets, *Assistant Professor of Physics and Applied Physics;* B.S., Ph.D., Massachusetts Institute of Technology.

Ye Yung Teng, *Assistant Professor of Physics and Applied Physics;* B.S., National Taiwan University, China; M.S., Ph.D., University of Maryland.

Jerry Waldman, *Assistant Professor of Physics and Applied Physics;* B.A., M.A., Columbia University; Ph.D., Massachusetts Institute of Technology.

Martin Wilner, *Professor of Physics and Applied Physics;* B.S., Rensselaer Polytechnic Institute; M.S., Yale University; Ph.D., Massachusetts Institute of Technology.

Chuen Wong, *Assistant Professor of Physics and Applied Physics;* Diploma of Science; Chung Chi College, Hong Kong; Ph.D., Case Western Reserve University.

Associates of the Graduate Faculty

Luther C. Barcus, *Associate Professor of Physics and Applied Physics;* B.A., University of Delaware; M.S., University of Miami.

Joseph G. Chervenak, *Adjunct Assistant Professor of Physics and Applied Physics;* B.S., St. Louis University; M.S., Ph.D., University of Missouri-Rolla.

Roger D. McLeod, *Associate Professor of Physics and Applied Physics;* B.A., Bowdoin College, M.S., Lowell Technological Institute.

James P. Phelps, *Adjunct Professor of Nuclear Engineering and Radiological Sciences;* B.S., University of Maine; Ph.D., Michigan State University.

Research Programs

Members of this Department are engaged in research programs in the following areas in which opportunities for advanced degree thesis research are offered: Theoretical and Experimental Nuclear Physics, Theoretical and Experimental Solid State Physics and Quantum Electronics. Theory of Elementary Particles and Quantum Field Theory, Relativity, Atmospheric Physics and Biophysics.

Major research facilities include a 5.5 MeV Van de Graaff accelerator, a one megawatt swimming pool reactor, and a PDP-9 32-6 computer in the Nuclear Center. A major facility for infrared studies of semiconductors and metals, including a 100 kilogauss

super-conducting magnet, a Fourier transformer spectrometer, and infrared far infrared lasers will be installed in the new Science Center, completed in 1975. The Institute's time-sharing computer will be available after its installation.

Entering Graduate Students

Every entering graduate student is assigned a departmental advisor, who will advise him on his program of study and other academic requirements, serve as his registration officer, help him to become acquainted with research opportunities in the department, and assist in selecting a thesis supervisor.

Entering graduate students are expected to have a sound background in intermediate level mechanics, electricity and magnetism, thermodynamics, statistical mechanics and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove that deficiency.

Master of Science Degree Program

The Master's program in physics provides an opportunity for advanced study and research in most of the areas mentioned above.

Subject Requirements

30 credit hours are required for the M.S. Of these, a minimum of 6 credits and a maximum of 12 credits may be for thesis, or, if a project is approved by the department in place of M.S. thesis, then a maximum of three credits will be allowed.

A candidate for the M.S. degree electing to specialize in a particular area of applied physics will be required to take a sequence of courses designed by the Department to develop skills in the chosen specialty no later than the end of the first year of study.

95-505-506 Mathematical Methods of Physics	(4-0)(4-0)8
95-511 Classical Mechanics	(3-0)3
95-515-516 Quantum Mechanics	(4-0)(4-0)8
95-558 Electromagnetic Theory I	(3-0)3

In addition, the student's advisor will assure himself that the student has attained an appropriate level of proficiency in all three of these topics.

Electives may be any course chosen from the list of physics courses acceptable for graduate credit, but not more than three credits may be for seminar or special topics courses. Some graduate courses offered by other departments are acceptable for graduate credit in physics, but only with the approval of the Physics Department.

Thesis or Project

After obtaining a research supervisor, each student must submit to the department for its approval two copies of a typewritten proposal, which is to be a brief description of the problem he proposes to solve for his thesis, and how he proposes to solve it, or a description of his project. This proposal must bear the written approval of the member or associate of the graduate physics faculty who has agreed to supervise the work. After completing the work, the student will submit three copies of a typewritten dissertation based on it to the department. He will then have to pass an oral examination administered by a committee of members of the department, including his research supervisor, based on, but not necessarily restricted to, the subject of his dissertation. A student who submits an M.S. Project in place of a thesis will be examined also on the subjects which all physics M.S. candidates are expected to know. (These are expected to be the subjects covered in the recommended M.S. course sequence.)

Language Requirements

There are no foreign language requirements for the Master of Science degree in Physics.

Doctor of Philosophy Degree Program

Objectives

The degree of Doctor of Philosophy in Physics signifies an advanced competence in the various areas of physics and also recognizes a significant and original contribution to physical knowledge. To achieve this the doctoral program is designed to provide the graduate student with the training necessary for conducting independent research at a professional level. Doctoral research may be carried out in all the areas mentioned above.

Course Requirements

At least 60 credit hours are required for the Ph.D. of which at the most 24 may be thesis research (95-701-702). However, credits in 95-701-702 accepted in partial fulfillment of the M.S. requirement may not be accepted for the Ph.D. requirement.

The following courses are required:

95-505-506 Mathematical Methods of Physics	(4-0)(4-0)8
95-511 Classical Mechanics	(3-0)3
95-515-516 Quantum Mechanics	(4-0) (4-0)8
95-558-559 Electromagnetic Theory	(3-0) (3-0)6
95-517 Advanced Quantum Mechanics I	(3-0)3
or	
95-518 Advanced Quantum Mechanics II	(3-0)3

Electives may be chosen from the list of courses acceptable for graduate credit in physics, but explicit department approval is required for graduate credit of 95-461. Topics in Nuclear Physics, and 95-472, Solid State Physics. Some graduate courses offered by other departments are acceptable for graduate credit in physics, but only with the approval of this department.

Colloquium
All full-time graduate students are required to attend department colloquium.

Language Requirement
A demonstration of proficiency adequate for reading technical articles in physics (level two) in French, German, or Russian.

Other Skills
Either (a) a demonstration of reading proficiency (level two) in a foreign language from among French, German, or Russian in addition to that used for the Language Requirement, or (b) a demonstration of proficiency in computer programming, which may be validated by achieving a grade of B or higher in 90-361, Digital Computer Programming, or AP 397, Computer Programming and Applications I, or by demonstrating equivalent competence to the Physics Department.

Qualifying Examination
Ph.D. candidates are expected to take the Ph.D. qualifying examination not later than the fall semester of the third year of full-time study. This will consist of written examinations on classical and modern physics at the graduate level, followed by an oral examination.

Thesis Requirements
A thesis proposal must be submitted, according to the procedures outlined above in the description of the Master of Science program. A student may not register for 95-701, Graduate Research, until he has passed the Ph.D. qualifying examination and his thesis proposal is approved. However, he may begin research sooner, and register for 95-711, Special Problems. The thesis is to be based on original research performed under the supervision of a member of the graduate faculty holding an earned Ph.D. degree, and written to conform to the requirements of the graduate school. Four legible copies of a typewritten original must be submitted to the department. Following this, the student must pass an oral examination conducted by his thesis committee, based on, but not necessarily limited to, his thesis. If a student wishes to do a thesis under the supervision of a member of the graduate faculty of another depart-

ment or of the University of Lowell Research Foundation, he must obtain the consent of the physics department.

Courses of Study

95-421G Statistical Thermodynamics **(4-0)4**
Prerequisite: Permission of Instructor *Sebastian*
An integrated study of thermodynamics and statistical mechanics: review of the experimental foundations and historical development of classical thermodynamics; probability and statistical methods of studying macroscopic systems; atomic basis of the laws of thermodynamics and microscopic definitions of thermodynamic quantities using the method of ensembles; entropy and related quantities; TdS equations, Maxwell relations, equations of state, and applications; canonical and grand canonical ensembles; phase transitions; quantum statistics; applications to radiation, magnetism, specific heats.

95-461G Topics in Nuclear Physics **(3-0)3**
Prerequisite: Permission of Instructor *Schier*
Not for graduate credit without explicit department approval.
This course is designed to familiarize the student with a few research areas in the field of nuclear physics. The topics selected will be covered in depth; they may vary from year to year, and they will be chosen from the following: Nuclear constitution, fundamentals of interaction forces, liquid drop model and stability energetics, cross sections, passage of ionizing radiations through matter, radioactive decay, alpha-decay, beta-decay and electron capture, gamma-decay and internal conversion, nuclear reaction systematics, fission and fusion, models of nuclear structure.

95-472G Solid State Physics **(3-0)3**
Prerequisite: Permission of Instructor *Teng*
Not for graduate credit without explicit department approval.
Crystal structures, X-ray and neutron diffraction. Lattice vibrations. The free electron and band models of metals. Semiconductors and applications. Dielectric and optical properties of solids. Magnetism. Superconductivity.

95-505-506 Mathematical Methods of Physics **(4-0) (4-0)8**
Prerequisite: Permission of Instructor *Karakashian*
Vector and Cartesian tensor analysis; matrices and determinants; partial differential equations, boundary value problems and special

functions. Numerical analysis and applications: theory of analytic functions; Green's functions.

95-507 High-Energy Physics **(3-0)3**
Prerequisite: PH 516 *Sebastian*
A survey designed for the nonspecialist. Elements of relativistic scattering theory, the quantum numbers and conservation laws of high-energy physics, strong and weak interactions, dispersion relations. Regge poles and unitary symmetry.

95-511 Classical Mechanics **(3-0)3**
Prerequisite: Permission of Instructor *Korff*
Lagrangian formulation (including Lagrange multipliers), the Kepler problem and Rutherford scattering; rotating coordinate systems and rigid body motion; small oscillations and stability problems; Hamiltonian formulation.

95-515-516 Quantum Mechanics **(4-0) (4-0)8**
Prerequisite: 95-511 *Kannenberg*
Wave packets and free particle motion, the wave function and the Schrodinger equation, the linear harmonic oscillator, the WKB approximation, central forces and angular momentum, spin, and time-dependent and independent perturbation theory. Scattering theory.

95-517-518 Advanced Quantum Mathematics **(3-0) (3-0)6**
Prerequisite: 95-516 *Staff*
The formal theory of scattering, Klein-Gordon and Dirac equations and simple applications; quantum theory of radiation. Symmetry principles and elements of group theory; introduction to many-body theory; Hartree-Fock self-consistent calculations and their applications to atomic, solid state, and nuclear physics.

95-522 Statistical Mechanics **(3-0)3**
Prerequisite: Permission of Instructor *Sebastian*
The classical statistical mechanics of Gibbs and Darwin-Fowler, the quantum statistical mechanics of Fermi-Dirac and Bose-Einstein, and applications to thermodynamics, solid-state physics, and nuclear physics.

95-558-559 Electromagnetic Theory **(3-0) (3-0)6**
Prerequisite: 95-505-506 Concurrently and Permission of Instructor *Couchell*
Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents.

Maxwell's equations, the Special Theory of Relativity. Waveguides. Mie scattering, radiation from an accelerated charge; plasma physics.

95-560 Applied Quantum Mechanics **(3-0)3**
Prerequisite: 95-515-516 *Sebastian*
Relativistic Dirac equation of the electron and its simple applications. Symmetry principles in quantum mechanics and elements of group theory. Introduction to many body theory. Hartree Fock self-consistent calculations, and their applications to the theory of many electron atoms, and the nuclei of atoms. Emission and absorption of radiation by quantum systems such as atoms and nuclei. Widths and intensities of spectral lines. Selection rules. Electric and magnetic multipole moments of nuclei and e.m. transition probabilities for nuclei.

95-561-562 Nuclear Physics **(3-0) (3-0)6**
Prerequisite: Permission of Instructor *Staff*
Stationary states of nuclei, nuclear charge radius, mass, moments, parity, and statistics; theory of alpha, beta, and gamma decay; fission reactions induced by charged particles, gamma rays, and neutrons; nuclear forces and nuclear models; and fast neutron physics.

95-573 Advanced Theory of Solids I **(3-0)3**
Prerequisite: Permission of Instructor and 95-516 *Stimets*
Lattice vibrations and their interactions with X-rays, neutrons and light. The band model of solids and energy band calculations. The Fermi surface. Transport and optical properties in metals and semiconductors.

95-574 Advanced Theory of Solids II **(3-0)3**
Prerequisite: 95-573 *Stimets*
Magnetism and magnetic resonance. Superconductivity. Many-body theory and its applications. Collective excitations. Green function techniques in solid state physics.

95-575-576 Neutral Particle Transport **(3-0) (3-0)6**
Prerequisite: Permission of Instructor *Beghian*
Boltzmann and integral transport equations. Spherical harmonic and variational methods. Corrections to diffusion theory. Special methods of solving transport equations. Adjoint functions. Applications.

95-581-582 Theory of Noise and Random Processes (3-0) (3-0)6
Prerequisite: 95-505-506 *Korff*
95-521-522 (May be taken concurrently)
Probabilities. Statistical analysis of random processes. Ensemble theory. Signals and noise in nonlinear systems. Information theory. Normally distributed random processes. Langevin, Fokker-Planck and Boltzmann equations. Thermal, shot and impulse noise. Linear measurements, prediction, and optimum filtering. A strong background in applied mathematics is required. Some knowledge of AC circuit theory and electronics would also be useful.

95-583-584 Gerneral Theory of Relativity (3-0) (3-0)6
Prerequisite: Knowledge of Special Relativity including Tensor Notation *Kannenberg*
Review of Newtonian gravitational theory and special relativity. The weak and strong principles of equivalence. Tensor analysis in Riemann spaces. Einstein's equations for the gravitational field. Classic tests of Einstein's theory; spherically symmetric solutions. Gravitational field theory and the canonical analysis of general relativity.

95-593-594 Graduate Laboratory (0-9) (0-9)6
Prerequisite: Permission of Instructor *Ring*
A laboratory course designed to acquaint the graduate student with the methods and techniques of modern experimental physics.

95-601 Seminar in Physics (1-0) (1-0)2

95-603 Seminar in Nuclear Physics (1-0) (1-0)2

95-605 Seminar in Solid State Physics (1-0) (1-0)2
Staff
Individual presentations by students and the instructor, of advanced topics: original research or journal articles. Given only when the demand is sufficient.

95-651 Selected Topics in Physics (3-0) (3-0)6

95-653 Selected Topics in Nuclear Physics (3-0) (3-0)6

95-655 Selected Topics in Solid State Physics (3-0) (3-0)6

95-657 Selected Topics in Theoretical Physics (3-0) (3-0)6
Staff
Recent advances, more advanced topics, not covered in the regular

courses in these topics. Given only when the demand is sufficient. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken twice for credit without repeating topics.

95-701 Graduate Research in Physics **(0-9) (0-9)6**
Prerequisite: Departmental Approval of a Written Thesis Proposal *Staff*
Research for M.S. or Ph.D. Thesis.

95-711-712 Special Problems in Physics **(0-9) (0-9)6**
Prerequisite: Permission of Instructor *Staff*
Reading in preparation for research (in subjects not offered in courses at the time the student wishes to study them), or research not for thesis. If results of the research are subsequently incorporated in a thesis, credits earned in 711-712 may be used to satisfy credit requirements in 701-702. If results are incorporated in an M.S. project, not more than three credits are allowed.

95-751-752 Advanced Projects in Physics **(0-3) (0-3)2**
Prerequisite: Permission of Instructor *Staff*
Independent reading or research not for thesis.

80-586 Semiconductors **(3-0)3**
Omar
Transport and optical properties of Semiconductors. Statistics, collision mechanisms, and band structure. Hot electrons. High magnetic field pheonomenon. Devices: Junctions and transistors: Gunn oscillators; semiconductor lasers. (This is the first of a proposed series of Applied Physics courses which is being developed.)

POLYMER SCIENCE

Members of the Graduate Faculty

Joseph C. Salamone, *Professor of Chemistry and Chairman of Department;* B.S., Hofstra University; Ph.D., Polytechnic Institute of Brooklyn.

Alexandre Blumstein, *Professor of Chemstry;* B.S., Sorbonne, France; Ph.D. University of Strasbourg, France.

Rita Blumstein, *Assistant Professor of Chemistry;* B.S., Sorbonne, France; Ph.D., University of Delaware.

Stuart B. Clough, *Associate Professor of Chemistry;* B.S., University of Massachusetts; M.Ch.E., University of Delaware; Ph.D., University of Massachusetts.

Stanley C. Israel, *Assistant Professor of Chemistry;* B.S., Parsons College; Ph.D., Lowell Technological Institute.

Chong Wha Pyun, *Associate Professor of Chemistry;* B.S., M.S., Seoul National University, Korea; Ph.D., Brown University.

Arthur C. Watterson, Jr., *Professor of Chemistry and Assistant Chairman of Department;* B.S. Geneva College; Ph.D., Brown University.

Master of Science Degree Program

The Polymer Science Program of the Department of Chemistry offers the student a unique opportunity for advanced study and research training in the rapidly growing field of macromolecular science. Provision is made to include the broadest coverage of both practical and theoretical aspects of polymer science, taking advantage of the unique facilities at University of Lowell in Chemistry of macromolecules, plastics technology and other related fields.

Diagnostic-Evaluation Examinations

During the week of registration each entering student must take written examinations in the fields of organic, physical and analytical chemistry. An evaluation examination in polymer science is offered to those who wish to be exempted from 97-503-504. Except for polymer science, the examinations are the ACS Graduate Level Placement Exams, and the student is expected to score higher than the 50th percentile for a passing grade. If a student should not qualify on any one of the examinations, he must take and pass a second examination in the same area in the second semester to be considered for the Ph.D. program.

Students performing well below the 50th percentile on three of four examinations are not allowed to register as graduate students, but must register as special students.

Subject Requirements

A candidate for the Master of Science Degree in Polymer Science must have a minimum of 18 credit hours of course work, exclusive of research and seminar, as well as complete a thesis based upon original research. Of the credit requirement, a minimum of 15 credits must be taken in the Department of Chemistry. The remaining course credits (three or more) may be taken in chemistry (polymer science) or in such related fields as plastics, physics, mathematics, biology or engineering. Credit is normally not allowed for 400 level subjects in chemistry, except for those so designated in the catalog or approved by a student's advisor. All students must take 97-601-602, Polymer Science Seminar, each year they are in residence. The first semester of Chemistry Seminar, 84-601, may be given concurrently with the first semester of Polymer Science Seminar.

Although the design of the academic program is the responsibility of the Student's Advisory Committee, the following listing provides a suggested core of subjects for program development.

First Semester Subjects

97-503	Advanced Polymer Science I	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
97-511	Biopolymers	(2-0)2
97-553	Organic Chemistry of Macromolecules	(2-0)2
97-601	Polymer Science Seminar	(1-0)1
97-707	Graduate Research in Polymer Science	(0-9)3
84-431G	Advanced Physical Chemistry	(3-0)3
84-523	Organic Reaction Mechanisms and Structure	(3-0)3

Second Semester Subjects

97-504	Advanced Polymer Science II	(3-0)3
97-506	Polymer Preparation and Characterization II	(0-4)1
97-512	Bulk Properties of Polymers	(2-0)2
97-602	Polymer Science Seminar	(1-0)1
97-708	Graduate Research in Polymer Science	(0-0)3
87-434G	Colloid and Surface Chemistry	(3-0)3
84-524	Organic Synthesis	(3-0)3
26-415G	Plastics Processing Techniques	(1-2)2

Language Requirements

There is no foreign language requirements for the master's degree in Polymer Science.

Thesis Examination

Each candidate for the master's degree must present himself for an oral examination in the field of polymer science before an examining

committee appointed by the Department Chairman from the graduate faculty in the Department of Chemistry. The examining committee will include the student's Advisory Committee plus an additional graduate faculty member. The chairman for the examination shall be the student's thesis advisor. While only members of the examination committee and the Dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Applications to take the examination must be filed by the student with the Chairman of the Department of Chemistry at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

Doctor of Philosophy Degree Program

Polymer Science Option

Students in the Ph.D. program in the Department of Chemistry may elect an option in Polymer Science. This optional program is designed to provide an advanced study in the special chemistry of polymers and the research training in their preparation and properties.

The examination system is the same as that described for the doctoral degree in chemistry with the following exceptions:

(a) The evaluation examinations required upon entrance to the program shall involve ACS Graduate Level Placement Exams in organic chemistry, physical chemistry and analytical chemistry. An evaluation examination in polymer science is offered to those who wish to be exempted from 97-503-504.

(b) A qualifying examination in polymer science is required. The student is required to take this examination at the end of the first academic year. Should a student fail this examination, he must take and pass a second examination prior to the start of the second academic year. A student may be exempted from this examination if he obtains an average of AB or better in PS 503-504 or its equivalent.

(c) Upon admission to the Ph.D. program the student must pass a series of cumulative examinations in various topics in polymer science. These examinations must be taken beginning the September following admission to the program, and they must be taken consecutively. The examinations are graded on a point basis, where the student can score zero, one or two points on each examination. In order to pass, the student must obtain a total of eight points in eight examinations or seven points in four successive examinations.

Subject Requirements

The credit requirements for the Ph.D. degree in Chemistry-Polymer Science Option are the same as those described for a doctoral degree in chemistry. Although the program of courses is made by the student's Advisory Committee, the subjects listed below provide a suggested nucleus for educational development. Each year the student is in residence he is required to attend and to participate in 97-601-602, Polymer Science Seminar.

The courses that are available in the first year include:

97-503	Advanced Polymer Science I	(3-0)3
97-504	Advanced Polymer Science II	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
97-506	Polymer Preparation and Characterization II	(0-4)1
84-431G	Advanced Physical Chemistry I	(3-0)3
84-432G	Advanced Physical Chemistry II	(3-0)3
84-523	Organic Reaction Mechanisms and Structure	(3-0)3
84-524	Organic Synthesis	(3-0)3

The courses that are available in the second and third year include:

97-511	Biopolymers	(2-0)2
97-512	Bulk Properties of Polymers	(2-0)2
97-549	Physical Chemistry of Macromolecules I	(2-0)2
97-550	Physical Chemistry of Macromolecules II	(2-0)2
97-553	Organic Chemistry of Macromolecules	(2-0)2
84-434G	Colloid and Surface Chemistry	(3-0)3
84-540	Chemical Kinetics	(3-0)3

26-415G, Plastics Processing Techniques and 84-531, Statistical Thermodynamics are strongly recommended electives. Other recommended electives include 84-515, Chemical Literature; 84-521, Physical Organic Chemistry; 26-503-504, Mechanical Behavior of Polymers; 26-506, Polymer Structure; and 26-513, New Plastics Materials.

Candidacy for the Doctorate in Chemistry — Polymer Science Option

To be admitted to candidacy for the doctorate, a student must:

1. Have a satisfactory record in undergraduate training, graduate seminar, and collateral reading.
2. Complete the course credit requirements.
3. Pass the diagnostic evaluation examinations, the qualifying examination, and the cumulative examinations.
4. Present an oral defense of an original research proposal.
5. Fulfill the language requirements.
6. Secure the approval of his Advisory Committee and the Chairman of the Department of Chemistry.

When these requirements have been fulfilled, the Department Chairman notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

97-503 Advanced Polymer Science I **(3-0)3**
Prerequisite: Permission of Instructor *Blumstein*
Introduction to chain statistics and thermodynamics of macromolecular solutions, methods of study of molecular weight and chain conformation, and the properties of polymers in bulk including viscoelasticity and crystallinity.

97-504 Advanced Polymer Science II **(3-0)3**
Prerequisite: Permission of Instructor *Salamone*
A study of the principles of condensation, free radical, ionic, coordination and ring-opening polymerization. The topics include the concepts of step-growth and chain-growth polymerization, the effect of polymerization techniques on reaction kinetics and molecular weight and molecular weight distribution, and the evaluation of reactivity ratios in copolymerization reactions.

97-505 Polymer Preparation and Characterization I **(0-4)1**
Prerequisite: Permission of Instructor *Staff*
A laboratory course designed to acquaint the graduate student with the techniques used in the syntheses and characterization of macromolecules.

97-506 Polymer Preparation and Characterization II **(0-4)1**
Prerequisite: Permission of Instructor *Staff*
An advanced laboratory in polymer science concerned with the instrumental study of macromolecules by utilization of osmometry, light scattering, gel permeation chromatography, vapor pressure osmometry, infrared spectroscopy, thermogravimetric analysis and differential thermal analysis.

97-511 Biopolmers **(2-0)2**
Prerequisite: Permission of Instructor *Salamone*
Conformation and configuration of vinyl polymers and polypeptides. Helix-coil transitions in proteins and polypeptides. Biological specificity and macromolecular structure. Synthesis of stereoregular polypeptides. Structure and physical properties of nucleic acids. Relations of synthetic polymers to naturally occurring polymers.

97-512 Bulk Properties of Polymers **(2-0)2**
Prerequisite: Permission of Instructor *Clough*
Structure and properties of bulk polymers in the glassy, rubbery, and crystalline states. Topics covered include chain statistics, rubber elasticity, crystalline polymers, glass transition, segmental motion and viscoelasticity.

97-549 Physical Chemistry of Macromolecules I **(2-0)2**
Prerequisite: 97-503 or equivalent *Pyun, Clough*
Physical chemistry of polymers, including structure and conformation, chain statistics, molecular weight distributions and averages, polymerization kinetics and classical and statistical thermodynamics of polymer solutions.

97-550 Physical Chemistry of Macromolecules II **(2-0)2**
Prerequisite: 97-549 or equivalent *Blumstein, Pyun*
Optical and hydrodynamic properties of polymer solutions. Methods of determination of structural parameters, including light scattering, viscometry, and other techniques.

97-553 Organic Chemistry of Macromolecules **(2-0)2**
Prerequisite: 97-503, 504 *Salamone*
An advanced study in polymer science concerned with the synthesis of macromolecules and their mechanisms of formation.

97-601 Polymer Science Seminar **(1-0)1**
Required of all Polymer Science graduate students
Presentation of current topics in polymer science by visiting scientists, faculty and graduate students.

97-651 Selected Topics in Polymer Science **(3-0)3**
Prerequisite: Permission of Instructor *Staff*
Advanced topics in various aspects of polymer science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge in the field of macromolecules.

97-707 Graduate Research in Polymer Science **(0-9)**
Staff
An independent investigation of a problem by the student in conference with a polymer science faculty advisor and approved by the Department Head. A clear and systematic written presentation of the results is required.

97-751 Advanced Projects in Polymer Science **(0-3)1**

Staff

Special projects undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by the Department Chairman.

RADIOLOGICAL SCIENCES AND PROTECTION

Members of the Graduate Faculty

Jesse Y. Harris, *Professor of Radiological Sciences and Chairman of Department;* B.S., M.S., M.S., Ph.D., Rutgers (the State University).

Kenneth W. Skrable, *Professor of Radiological Sciences,* B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers (the State University) (C.H.P.).

Edward L. Alexander, *Professor of Radiological Sciences and Director of the Research Foundation,* B.S., M.S., University of Maine; Ph.D., Vanderbilt University.

Anthony Liuzzi, *Associate Professor of Radiological Sciences;* B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., New York University (C.H.P.).

Associates of the Graduate Faculty

George E. Chabot, *Adjunct Assistant Professor of Radiological Sciences,* A.B., Harvard University; M.S., Harvard School of Public Health.

Master of Science Degree Program

With the increasing uses of radiation and radioactive materials and the projected increase in the utilization of nuclear power, there will be a growing need for research in Radiological Sciences and Protection. The excellent facilities, equipment, and supporting staff available at the University of Lowell Nuclear Center and faculty in the Radiological Sciences Department and in other allied departments give students at the University of Lowell a unique opportunity to make significant contributions to research in the field.

The master of science degree program in Radiological Sciences and Protection offered by the Department of Radiological Sciences is interdisciplinary in nature and should be attractive to engineering students and students in the biological and physical sciences. The program is complimentary to the master of science degree program in Environmental Studies enabling students at the University of Lowell to pursue careers in all of the major areas of environmental protection.

Students are given the opportunity to select programs which respond to the growing manpower needs arising from the increasing use of nuclear energy sources and the increasing uses of radiation and radioactive materials in industry, government, and medicine. For example, the current energy crisis which has resulted from the high level of concern exhibited today regarding the environment has created a critical shortage of professionals needed to perform evaluations of the environmental impact of nuclear reactors and fuel reprocessing plants. Through the close alliance of the programs in Radiological Sciences and Protection and in Environ-

mental Studies, students at the University of Lowell are given the opportunity to obtain a certain perspective and education, training, and professional development required for such positions.

Prerequisite
A student should have a reasonable minimum preparation including courses in mathematics, chemistry, physics, biology and in nuclear and radiological sciences similar to the University of Lowell Radiological Health Physics undergraduate curriculum.

Plan of Study
The program allows a student to select courses and a thesis project depending on his research interest and desired area of professional development. Various opportunities for research and professional development are possible through the use of the Nuclear Center of the University of Lowell and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A thesis research advisor, other than a University of Lowell faculty member, may be approved for the conduct of research at facilities outside of the University. A student's program must receive departmental approval.

Thesis or Project
A satisfactory Master's thesis or Master's project is required, the subject and scope of which must be approved by the student's Committee and must satisfy the requirements of composition and style specified by the Graduate School.

Oral Defense
A thesis Committee is appointed by the head of the Department to read a student's thesis and to listen to an oral defense presented by the student. In general, the Committee will include the thesis advisor and two additional members chosen from the Radiological Sciences Department and other departments in which the candidate has taken graduate studies.

Examinations
Degree candidates electing the project option are required to pass a comprehensive written and/or oral examination administered by the departmental graduate committee. This examination will normally be administered during the semester that the student completes his course requirements for the M.S. degree.

Residence
No residency requirements are specified.

Foreign Language
No language requirements are specified by the Department.

A core curriculum consisting of five courses and research or advanced projects in Radiological Sciences and Protection are required of all students pursuing the Master's degree in Radiological Sciences and Protection. These core courses are listed below along with other courses offered by the Department for graduate credit. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies, Biology, Mathematics, Meteorology, Chemistry, and others may be selected for graduate credit with the approval of the Department.

Required Core Courses

98-401G	Radiation Safety or Control I (or equivalent)	3
98-402G	Radiation Safety or Control II (or equivalent)	3
81-462G	Radiation Biology (or equivalent)	3
98-501	Radiation Physics and Shielding Design	3
98-506	Radiation Dosimetry	3
98-601-602	Graduate Project in Radiation Science and Protection (Project option)	3-6
98-701-702	Graduate Research in Radiological Sciences and Protection (Thesis option)	9

Courses of Study

98-401G Principles of Radiation Safety and Control (3,0)3
Skrable

Introduction to radiation protection, including radiation sources, radiation dose and dose measurement, radiation exposure, radiation protection techniques, monitoring methods and instruments, contamination control and waste storage, facility design, hazards analysis, and applied health physics techniques for the safe handling and control of radioactive material.
Prerequisite: 80-202 or equivalent.

98-402G Principles of Radiation Safety and Control (3,3)4
Skrable

A laboratory course giving students experience with equipment and practices of current use in the radiation protection field, an extension of 98-401 giving some of the practical aspects of radiation safety and control. Prerequisite: 98-401.

98-403G Numerical Lab In Radiation Safety & Control (0,2)1
Skrable

Extensive problem solving with examples applicable to practical aspects of radiation safety and control. Use will be made of electronic calculators and/or computers in problem solutions. Prerequisite: 98-401, concurrently.

98-422G Environmental Radiation and Nuclear Site Criteria (3,0)3
Harris

Sources of radioactive waste and waste treatment; internal dosimetry, maximum permissible concentrations; distribution of radioactivity and the environment and the significance of releases to the air, aquatic and terrestrial ecosystems; design and operation of environmental surveillance programs around nuclear facilities; reactor site criteria, licensing, regulations, credible accidents, meteorological considerations, normal and abnormal operations; environmental impact of nuclear reactors. Prerequisite: Radiological Science 98-401 or equivalent.

98-441G Radioisotope Techniques (3,0)3
Harris

A course for students and staff designed to acquaint them with the theory and use of radioisotopes and the principles and operation of radiation counting systems. Lecture sessions are topics related to biological effects of radiation exposure, safe use of radiation sources, radiation protection techniques and procedures, and design of radiation facilities. Prerequisite: Biology senior or equivalent background.

98-443G Radioisotope Techniques Lab I (0,3)1
Harris

Laboratory experience in tracer techniques and appropriate use of various types of laboratory counting instruments. Prerequisite: 98-441 concurrently or equivalent.

98-451G Introduction to Electronic Product Radiation (3,0)3
Staff

The theoretical and applied aspects of the generation, measurement, and uses of radiant energy from electronic products whose emissions span the entire electromagnetic spectrum: ultrasonic energy emitted by electronic products, biological effects, standards of protection and control, and consequences and intent of Public Law 90-602. Prerequisite: 98-401.

98-502 Radiation Physics and Shielding Design (3,0)3
Liuzzi

Interaction of neutrons, gamma rays and charged particles with matter; buildup factors; shielding of point, surface, and volume sources; shielding design factors in reactor and accelerator operation. Prerequisite: permission of instructor, Advanced Calculus and Radiological Sciences grad. student or equivalent.

98-503 Introduction to Radiation Chemistry **(3,0)3**

Alexander

A study of the interaction of all types of ionizing radiation with matter and the resulting radiation-induced chemical reactions; excitation, ionization, and free radical formation and recombination. Prerequisite: permission of instructor. (Not offered every year)

98-504 Radiation Physics and Shielding Laboratory **(0,3)1**

Staff

Laboratory coordinated with 98-501 with applications to health physics problems. Prerequisite: 98-502 concurrently. (Not offered every year)

98-505 Radiation Dosimetry **(3,3)4**

Liuzzi

Sources of radiation exposure; calculations of chronic and acute radiation doses and their effects; internal dosimetry including distribution and elimination of radioisotopes; alpha, beta, gamma, and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments including solid state dosimeters, ion chambers, and extrapolation chambers. Prerequisite: permission of instructor, Radiological Sciences grad. student or equivalent.

98-507 Radiation Dosimetry Laboratory **(0,3)1**

Staff

Laboratory experience coordinated with lecture sequence in 98-505. Prerequisite: 98-505 concurrently. (Not offered every year)

98-508 Environmental Toxicology and Epidemiology **(3,0)3**

Harris

Study of the systems of the body with respect to the sites and modes of action by various toxic agents. Discussion of procedures for evaluation of toxicity of radioactive and non-radioactive agents. Determination of TLV and LD_{50} values. Review of status of current epidemiology studies of effects of radiation and other toxic agents. Discussion of occupational environments with respect to standards, control measures, and current problems. Review of standards for protection of the environment and the general public. Prerequisite: grad. student with science background or permission of instructor. (Offered odd-numbered years)

98-510 Environmental Toxicology Laboratory **(0,3)1**

Harris

Laboratory experiments on the effects of toxic agents on plant and

animal systems with emphasis on radiation and air pollutants. Prerequisite: 98-508 concurrently. (Offered odd-numbered years)

98-601 Graduate Project in Radiological Sciences and Protection **(0,10)3**

Staff

This course is taken by those Masters Degree candidates electing the project option. The Master's project consists of a scholarly investigation such as a review, report, design, etc. in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student's advisor in advance, and the final report must be approved by the departmental graduate committee. The final report should conform to the format specified in the Thesis Guide, which is available in the Graduate School Office. A maximum of three credits is allowed for the graduate project. Prerequisite: completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of faculty advisor.

98-651 Special Topics in Radiological Sciences **(3,0)3**

Staff

This course is used to provide students with current information on topics of interest to graduate students in Radiological Sciences and Protection. Course may include preparation and presentation of lectures applicable to training of health physics technicians. Topics covered may vary from year to year. Topics are announced prior to registration. Prerequisite: Radiological Sciences and Protection graduate student.

98-652 Special Topics in Radiological Sciences **(3,0)3**

Staff

See 98-651.

98-701 Graduate Thesis in Radiological Sciences and Protection **(0,10)3**

Staff

The Master's thesis will generally consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. A maximum of nine credits is allowed for the graduate thesis. Details of proposal and report requirements can be obtained

from the department graduate committee chairman. Prerequisite: completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and thesis proposal approved by departmental graduate committee.

98-702 Graduate Thesis in Radiological Sciences and Protection **(0,10)3**
Staff

See 98-701.

98-751 Advanced Projects in Radiological Sciences **(0-3)1**
Staff

An opportunity for individual study under the direction of a staff member of topics related to radiological sciences and protection.

INDEX

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